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Environmental Science And Engineering, Inc.

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- PROVIDE A BASIS FOR DETERMINING LEVELS OF CHEMICALS THAT ARE ADEQUATELY PROTECTIVE OF PUBLIC HEALTH

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TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Operable Unit
Endangerment Assessment/Feasibility Study

Revised Draft Final Report

Volume I of VII
(Introduction)

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Harding Lawson Associates
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PROGRAM MANAGER FOR ROCKY MOUNTAIN ARSENAL

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THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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PREFACE TO THE DRAFT FINAL ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY

The Rocky Mountain Arsenal Offpost Operable Unit (OU) Endangerment Assessment/Feasibility Study (EA/FS) is presented in seven volumes. The contents of each volume are outlined below. To assist the reader, the complete Table of Contents is included at the beginning of each text volume; appendix volumes include a list of appendixes in the front. Tables and figures for each volume are included at the end of that volume for the sections included in the same volume. The Introduction, EA, FS, and each appendix have separate reference lists.

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- Preface EA/FS - explanation of the organization of the EA/FS report
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- Introduction to the EA/FS - introductory material common to both the EA and the FS, including site history and nature and extent of contamination at the Offpost OU
- Glossary EA/FS - list of acronyms used in the EA/FS

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- Section 2.0 EA - Exposure Assessment
- Section 3.0 EA - Toxicity Assessment
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- Section 2.0 FS - Development of Remedial Action Objectives and Screening of Technologies
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- Section 5.0 FS - Detailed Analysis of Alternatives
- Section 6.0 FS - Selection of the Preferred Site-wide Alternative
- Section 7.0 FS - References
- Volume VI Tables FS - tables for Sections 3.0, 4.0, 5.0, and 6.0 of the FS
- Volume VI Figures FS - figures for Sections 3.0, 4.0, 5.0, and 6.0 of the FS

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- List of FS Appendixes
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EXECUTIVE SUMMARY

This Revised Draft Final Endangerment Assessment/Feasibility Study (EA/FS) supersedes the Draft Final Offpost Operable Unit (OU) EA/FS, issued in March 1989. The Revised EA/FS is consistent with the National Contingency Plan (NCP), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the regulations implementing the National Environmental Policy Act of 1969 (NEPA).

ENDANGERMENT ASSESSMENT

An Endangerment Assessment was performed for the Offpost Operable Unit (OU) of Rocky Mountain Arsenal (RMA). The Offpost OU consists of 27 square miles located to the north and northwest of RMA. It is currently characterized by rural agricultural and residential land uses, with some industrial land use. In the future, land use is projected to change to more commercial, industrial, and recreational land use in areas adjacent to RMA, with some areas zoned for residential development. For these reasons, a rural residential scenario (including agriculture), a commercial/industrial scenario, and a recreational scenario were evaluated. An ecological assessment was also performed, due in part to the bald eagle habitat and other sensitive environments in the Offpost OU. The major steps performed in the EA included data evaluation, identification of chemicals of potential concern, exposure assessment, toxicity assessment, human risk characterization, and ecological assessment.

Identification of Chemicals of Potential Concern

Chemicals of potential concern (COCs) were identified by medium. The primary criterion for identification of COCs was a statistically significant increase in concentration in samples collected from the Offpost OU when compared with samples from locations believed to be unaffected by RMA contamination (i.e., background).

The statistical procedures used in this assessment to determine whether chemical concentrations were elevated above background levels contained several conservative elements when compared with procedures recommended by published guidance. These conservative elements

were included to compensate for small sample size and low frequency of detection above certified reporting limits in some of the data sets. The conservative features built into the statistical procedure exceeded published guidance and resulted in the inclusion of four groundwater COCs, two surface-water COCs, and one surface soil COC that would normally not have been included.

Thirty-four COCs were identified for groundwater, including nine pesticides, five inorganic compounds, and 20 volatile or semivolatile organic compounds. Ten COCs were identified for surface water, including four pesticides, two organic compounds, and four inorganic compounds. Each is also a COC for groundwater, the primary source of offpost surface-water contamination.

The six COCs identified in sediments are all pesticides. These COCs are associated with groundwater and/or surface water that interacts with the sediments in First Creek. Six pesticides were identified as COCs in surface soils.

All of the thirty-four COCs were evaluated for biota; however, only those COCs for which a complete pathway of exposure existed for a specific receptor organism were evaluated in the ecological assessment.

Exposure Assessment

The major elements of the exposure assessment included fate and transport of COCs, characterization of the exposure setting and exposure pathways, quantification of exposure, and an uncertainty analysis of calculated exposure intakes.

Chemicals migrated to the Offpost OU as a result of past operations at RMA, primarily by shallow groundwater and airborne pathways . Contaminant transport by both pathways has been controlled by onpost interim remedial actions. Offpost OU surface water was contaminated primarily by the natural interaction with offpost groundwater. Offpost OU surface soil was contaminated by the deposition of airborne contaminants, non-RMA-related intentional agricultural application of pesticides, and irrigation practices. Air monitoring data indicate that the air pathway does not contribute to human exposure.

The COCs exhibit great variability in their mobility and persistence in environmental media. Organochlorine pesticides are relatively immobile and persistent, tending to associate with soils

and sediments and tending to bioaccumulate in the food chain; the organochlorine pesticides are the only COCs elevated above background levels in soils and sediments. Most of the remaining COCs are mobile in groundwater, and the aromatics and aliphatics are volatile in surface waters. The fate properties of the COCs tend to determine their distribution in the Offpost OU.

Groundwater containing elevated levels of COCs exists north and northwest of RMA in three distinct plumes with characteristically different groundwater quality conditions. These flow paths are referred to as the northern paleochannel, due north of the RMA north boundary; the First Creek paleochannel, paralleling First Creek to the northwest from the RMA north boundary; and the northwest paleochannel, west of the RMA northwest boundary. The northern and First Creek paleochannels comprise the North Plume Group, and the northwest paleochannel is referred to as the Northwest Plume Group. The alluvial flow system transports most of the contamination in paleochannels characterized by coarser sediments. Groundwater traveling through the First Creek paleochannel discharges to First Creek, probably seasonally, resulting in elevated levels of several COCs in First Creek. First Creek discharges to O'Brian Canal. Concentrations of COCs are reduced substantially upon discharge to O'Brian Canal; only two COCs (diisopropyl methylphosphonate [DIMP] and fluoride) are elevated in the Canal.

Land use in the Offpost OU has been predominantly agricultural and rural residential, with localized commercial/industrial land uses and open space. The portion of the Offpost OU north of O'Brian Canal, where irrigation water is available from Burlington Ditch, contains many vegetable and turf farms. A recent change in land use affecting exposure to COCs was the purchase of former residential properties near the intersection of 96th Avenue and Peoria Street by Shell Oil Company. Based on local planning documents, it is expected that development resulting from encroachment of the Denver suburban fringe from the southwest and the new regional airport to the east will supplant agricultural land uses with residential and commercial/industrial land uses over the next 20 years.

The predominant traditional agricultural land use of the area supports the evaluation of exposure pathways involving consumption of foods produced in the Offpost OU. A complete

pathway must have a source, a mechanism of release, a transport medium, an exposure point (e.g., humans must be present to be exposed), and an exposure route (e.g., ingestion). The most important pathways considered under the residential reasonable maximum exposure (RME) scenario, including hypothetical future exposure pathways that may not be complete at this time, are direct ingestion of groundwater, inhalation of volatile COCs released from groundwater used for domestic purposes (e.g., showering, cooking), and consumption of vegetables, meat, eggs, and dairy products produced in the Offpost OU. Exposure concentrations in foods were estimated using equilibrium partition models. Predictions by the models were compared to limited site-specific sampling and analytical data, and the model results approximated the limited number of observed concentrations in meat and eggs. Data for milk and vegetables were insufficient to verify the models.

Current and projected future commercial/industrial and open space/recreational land uses in the area suggested that exposure pathways consistent with these land uses should be evaluated. The most important pathways considered in the RME commercial/industrial scenario are direct ingestion of groundwater and inhalation of volatile COCs from other uses (e.g., showering). The important pathways in the recreational scenario are dermal exposure to and ingestion of sediments.

For purposes of the EA, the Offpost OU was subdivided into six geographic zones, each with distinct exposure conditions. Variations in medium-specific exposure concentrations and land and water use were considered in defining these zones, which are shown in Figure ES1. A separate exposure assessment was performed for each zone. Hypothetical future intakes under the RME scenario are greatest in zones 2, 3, and 4, directly north of the RMA north boundary.

Exposure factors used in this EA conformed to U.S. Environmental Protection Agency (EPA) RME guidance wherever applicable factors existed. Where EPA guidance was not available, RME exposure factors were derived for the 95th percentile of the range of the exposure factor. COC intakes were estimated for lifetime, chronic, and acute exposure durations. The lifetime scenario begins at age 0 and extends for 30 years, considering age-dependent body weight, milk consumption, and direct ingestion of soil. Intakes were estimated for children and

adult women to address potentially sensitive subpopulations. The child chronic scenario assumes an exposure duration from ages 1 to 9. Children tend to be exposed at greater rates than adults, so the child chronic scenario represents the RME for chronic noncarcinogenic risk assessment. Commercial/industrial intakes were estimated for adult workers with a 25-year duration, while intakes for the recreational scenario were estimated for adults (30-year duration), and children (5-year duration).

The RME COC intake estimates include hypothetical exposure pathways that have not been complete for several years (i.e., exposure has not occurred by these pathways). For example, previous residents in zones 3 and 4 and current residents in zone 5 have water supplies other than shallow wells. There are no current residents in zones 3 and 4. Therefore, rural residential intake estimates in these zones are conservative because the pathways do not represent existing exposures.

A limited quantitative uncertainty analysis was performed to evaluate the possible exposure variation among the potentially exposed population. The uncertainty analysis shows that more than 98 percent of the population would never experience intakes as great as the RME. Considering the magnitude of the intakes, this value is much more conservative than the EPA RME guidance of 95 percent. The uncertainty analysis combines uncertainty in defining exposure concentrations (from monitoring data and models) and variability in hypothetical exposures. The uncertainty analysis process demonstrates that most of the variance in intake estimates can be attributed to variability across the population rather than uncertainty in defining the exposure concentrations.

Toxicity Assessment

Available information on the toxic effects of the COCs, emphasizing information pertinent to the evaluation of subchronic and chronic exposures at relatively low intakes, is summarized in the toxicity assessment section of the report. Available reference doses and cancer slope factors published by EPA were used in this EA. When chronic reference doses were unavailable from EPA, they were estimated or identified from other sources, particularly the RMA onpost toxicity assessment contained in the Final Human Health Exposure Assessment (Ebasco, 1990).

Two of the COCs, arsenic and benzene, are known human carcinogens (EPA category A). Ten COCs are probable human carcinogens (EPA category B2). Category B2 chemicals have sufficient evidence that the chemical causes cancer in laboratory animals, but insufficient evidence for cancer in humans. Most of the COCs have the potential for noncarcinogenic effects on the liver (hepatic system), and these chemicals were grouped to evaluate the probability of adverse effects on the liver.

The potential effects of the contaminants on terrestrial wildlife, livestock, terrestrial vegetation, and aquatic organisms were also summarized in the toxicity assessment section of this report. Toxicity reference values for biota were developed, which are intended to represent exposure levels that would result in a low probability of adverse effects on a population of nonhuman receptors, rather than to protect every individual animal. However, toxicity reference values derived for endangered species, such as bald eagles, are intended to be protective of individual animals. The potential for ecological effects was also evaluated by comparing observed tissue concentrations of COCs in biota samples to maximum allowable tissue concentrations, which are summarized in the toxicity assessment.

Human Risk Characterization

Additive carcinogenic risks for residential hypothetical future exposures at RME intake levels by zone are highest in zones 2, 3, and 4. These zones are south of O'Brian Canal and within approximately one mile of the RMA north boundary. Based on the uncertainty analysis, the hypothetical risks are likely to be overstated by threefold. Hypothetical cancer risks (without considering additional remediation) in each of these zones are estimated to be less than 8×10^{-4}. More than 80 percent of the risk in each of these zones is attributable to aldrin, chlordane, chloroform, dibromochloropropane, and dieldrin, all category B2 human carcinogens. Thus, the risk estimate is critically dependent on the extrapolation of toxicological data from animals to humans. Dieldrin's contribution to hypothetical future cancer risk is greater than any other chemical in all zones.

Anthropogenic dieldrin in surface soils is associated with agricultural practices in the Offpost OU. The hypothetical carcinogenic risk associated with dieldrin in soil resulting from agricultural practices in zones other than zone 3 and 4 is 1.5×10^{-4}. In addition, naturally occurring arsenic in groundwater contributes approximately 4.4×10^{-5} risk. Summing these two risks yields a 1.9×10^{-4} risk that is not attributable to RMA.

More than 95 percent of the residential hypothetical carcinogenic risk in each zone is attributable to the following pathways, listed in order of their contribution to risk:

1. Ingestion of groundwater
2. Consumption of homegrown vegetables
3. Ingestion of locally produced milk
4. Ingestion of locally produced eggs
5. Inhalation of volatiles via domestic use of groundwater (e.g., showering, cooking)
6. Ingestion of locally produced meat

Dermal exposures for all media do not contribute significantly to carcinogenic risk for the residential exposure, nor does incidental ingestion of soil and sediments. The oral exposure route for all media accounts for more than 80 percent of total carcinogenic risk, with the remainder predominantly by inhalation.

Groundwater is the dominant source medium contributing to total carcinogenic risk in zones 2, 3, 4, and 5, accounting for 55 to 80 percent of total risk, depending on the zone. In the remaining zones where groundwater concentrations are lower, soil is the most important medium, and soil alone contributes a risk from agricultural practices of approximately 1.5×10^{-4} in all zones. Groundwater, surface water, and soil may contribute to estimated risks via multiple pathways, specifically those involving food production within the Offpost OU. Groundwater and surface water are assumed to be used for irrigation of vegetable crops and watering of livestock. Each of the food pathways may also accumulate COCs from soil, and these relationships are quantified via the equilibrium partition models.

Hypothetical risks from all carcinogens are added to determine total carcinogenic risk regardless of target organ/system or weight-of-evidence category. The dominant contribution to total carcinogenic risk in all zones is from category B2 carcinogens, as previously presented. Carcinogenic risks are also posed by arsenic, a category A human carcinogen.

Hypothetical future noncarcinogenic effects were evaluated for all COCs by calculating a hazard index (HI), which is the estimated intake divided by a reference dose. An HI of greater than 1.0 warrants further evaluation. Children are a potentially sensitive subpopulation in the residential scenario with the largest potential for adverse noncarcinogenic effects, due to higher intakes. Considering the target organ/system potentially affected by each of the COCs, the most probable noncarcinogenic effect would be to the liver. The maximum hypothetical future additive child chronic HI for liver toxicants is 6 in zones 3 and 4. Central nervous system effects are also a potential, although smaller, risk. DIMP (based on acute effects only) and manganese combine to yield an HI of 3 in zone 4.

RME estimates of hypothetical current carcinogenic risks for residential land use are substantially less than future hypothetical risks. No one resides in zones 3 and 4; hence, there is no hypothetical current risk for these zones. Residents in zones 1B and 2 do not use water from the shallow aquifer. Consequently, the domestic use groundwater pathway is not and has not been complete in these zones for several years. Hypothetical current risks in zones 1B and 2 are at least 3 to 4 times lower than the hypothetical future RME estimates.

For the commercial/industrial RME scenario, hypothetical future carcinogenic risks in zones 3, 4, and 5 are approximately 1×10^{-4}, with 85 percent of the risk in each zone from aldrin, dieldrin, and arsenic. Carcinogenic risks for the recreational subgroup are approximately 2×10^{-6} for zones 3 and 4. Greater than 90 percent of the risks are attributable to dieldrin and aldrin. The estimated chronic HIs (liver toxicants) for the commercial/industrial and recreational scenarios in zones 3, 4, and 5 are less than 1 except for the commercial/industrial scenario in zone 4 which is 1.8.

Ecological Assessment

The objective of the ecological assessment was to determine hypothetical adverse affects of COCs on the environment and nonhuman receptors. Two major natural ecosystem types occur in the Offpost OU: terrestrial and aquatic. There is also extensive agricultural use of the area.

Potential hazards to the different ecological components of the Offpost OU were addressed by considering the hazards to terrestrial, aquatic, and agricultural biota separately. Bioaccumulation and direct toxicity endpoints were evaluated for terrestrial and aquatic life; only direct toxicity was evaluated for underwater aquatic life and agricultural life. Maximum allowable tissue concentrations (MATCs) were developed to assess risk from tissue residues as a function of bioaccumulation. The predicted tissue concentrations for aldrin, dieldrin, endrin, DDE, and DDT did not exceed the MATC for the bald eagle via the terrestrial food web; however, the endrin MATC for the owl and kestrel was exceeded for zone 3. The ratio of predicted tissue concentrations of dieldrin, DDE, and DDT to MATC in the aquatic food web for the bald eagle exceeded one. Exceedances were also reported for the great-blue heron (DDE and DDT) and the mallard (DDE). In addition, exposure concentrations or intakes were compared to acceptable intakes, such as toxicity reference values or reference media concentrations, resulting in an HI. The estimated intake of DDE, DDT, dieldrin, and endrin for the bald eagle exceeded the toxicity reference values, yielding an HI of greater than 1 for these COCs. Although an HI greater than 1 may indicate a potential hazard to the receptor species, HIs for mobile species, such as the bald eagle, should be interpreted in terms of size of home range. Therefore, the assumption made in this EA that exposure originates entirely from zones 3 and 4 for the bald eagle is conservative; spatially, these zones are far smaller than the bald eagles' reported range.

Endangerment Assessment Conclusion

The objectives of the EA were to provide an analysis of risks in the absence of additional remediation (baseline risks) and to provide a basis for determining the need for action at the Offpost OU. The EA for the Offpost OU has identified hypothetical carcinogenic risks and

hazard indices that exceed the acceptable risks as defined by the revised NCP (EPA, 1990) and the Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA, 1991).

Based on these findings, remedial action as defined by CERCLA may be warranted for the Offpost OU. Accordingly, a Feasibility Study has been prepared as a companion document to the EA for the Offpost OU.

FEASIBILITY STUDY

Based on the results of the EA, the FS developed and evaluated a range of remedial alternatives consistent with the NCP. Based on the evaluation presented in this FS, the Army selected a preferred site-wide alternative, which is consistent with CERCLA and the NCP. The FS shows that the preferred site-wide alternative meets the statutory requirements of CERCLA and the NCP. The major steps performed in the FS include: development of remedial action objectives (RAOs), development and screening of remedial alternatives, detailed analysis of remaining alternatives, and selection of the preferred site-wide alternative.

Development of Remedial Action Objectives

The development of RAOs consisted of three steps:

- Identification of COCs by medium
- Identification of media of concern
- Identification of exposure pathways.

Six media were evaluated in the remedial investigation (RI) for the Offpost OU: groundwater, soil, surface water, sediment, air, and biota. Each medium was evaluated in the Offpost EA/FS with respect to (1) the nature and extent of contamination, (2) potential exposure pathways and associated risk characterization, and (3) development and analysis of potential remediation approaches and their impact on the other media. Groundwater, soil, surface water, and sediment were identified as media of concern. Air was not identified as a medium of concern on the basis that air monitoring data have indicated air quality within the Offpost OU is not impacted by contaminants related to RMA. Biota were not identified as a medium of concern.

Direct remediation of biota was not included on the basis that it is not effective except by methods that temporarily eliminate receptor species from the contaminated area. However, protection of biota was addressed through the development of ecological criteria for the protection of species potentially at risk.

Potential pathways of exposure to humans and ecological receptors were identified in the EA for groundwater, soil, surface water, and sediment. These pathways were addressed directly in the development of RAOs for each medium.

The RAOs specify the attainment of preliminary remediation goals (PRGs) for the identified COCs, media, and exposure pathways. In accordance with the NCP, PRGs were developed considering aplicable or relevant and appropriate requirements (ARARs), health-based criteria, factors related to technical limitations (e.g., analytical detection limits), land use, background concentrations, and ecological criteria. Final remediation goals will be determined when the remedy is selected and the Record of Decision is issued.

Groundwater exceedances of PRGs were identified in two plume groups, the North Plume Group and the Northwest Plume Group, an area encompassing approximately 590 acres in the Offpost OU. Groundwater alternatives were developed to address the areas of PRG exceedances.

Comparison of PRGs with measured concentrations of COCs in Offpost OU soil and sediment indicates that none of the COCs exceed PRGs. Therefore, remediation of Offpost OU soil and sediment is not required.

First Creek is the only surface-water body with COC concentrations exceeding PRGs. The two primary sources of contaminants detected in samples from First Creek are discharging groundwater (for organic contaminants) and surface-water flow from onpost RMA (for arsenic contamination). Direct treatment of First Creek surface water is not a necessary or appropriate response action to achieve surface-water RAOs. Remediation of groundwater in the Offpost OU will address the primary source of organic COCs detected in First Creek surface water, and arsenic will be addressed by alternative sewage treatment onpost, which would eliminate existing surface water discharge to First Creek. Therefore, development of surface-water remedial

alternatives is not necessary; however, surface-water PRGs were considered during the development and screening of alternatives.

Development and Screening of Remedial Alternatives

Remedial alternatives for the Offpost OU were developed by (1) identifying the media in which COCs were detected at levels exceeding PRGs, (2) calculating the areas and volumes of media exceeding PRGs, and (3) assembling combinations of representative process options into alternatives representing a range of treatment and containment combinations that address the RAOs. Consistent with the NCP, a range of alternatives for groundwater was developed from no action to complete removal or destruction of contaminants exceeding PRGs.

Use of Groundwater Modeling in Alternatives Development

To aid in the analysis of groundwater alternatives, two numerical models (North Plume Group and Northwest Plume Group) were prepared to simulate the groundwater flow and dissolved chemical transport in the Offpost OU. Due to the approximate nature of the models, and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the modeling results should be construed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives. Simulations of contaminant transport were made corresponding to the No Action alternative and other configurations for both the North and Northwest Plume Groups. Initial conditions were chosen to reflect the contaminant plumes and to reflect contaminant removal at the North Boundary Containment System (NBCS) and Northwest Boundary Containment System (NWBCS) consistent with attainment of Offpost OU PRGs at the boundary systems.

North Plume Group Alternatives

After screening several extraction/recharge configurations, the following groundwater alternatives were developed for the North Plume Group. The major components of each alternative are also listed.

Alternative No. N-1: No Action

The components are as follows:

- Long-term groundwater monitoring
- 5-year site reviews

This alternative was retained for the detailed analysis step as required by the NCP.

Common to the following alternatives are long-term groundwater monitoring and 5-year site reviews, as well as the Army's commitment to provide alternate water to any identified future users of groundwater exceeding PRGs (i.e., exposure control).

Alternative No. N-2: Continued Operation of the North Boundary Containment System with Improvements as Necessary

The major components are as follows:

- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- 5-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-3: Land Acquisition and Use Restrictions

The major components are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring

- 5-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Alternative No. N-4: Interim Response Action A

The major components are as follows:

- Removal of contaminated unconfined groundwater north of the RMA boundary in the First Creek and northern paleochannels using groundwater extraction wells
- Treatment of the organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater using wells and trenches
- Continued operation of the NBCS
- Improvements to IRA A and the NBCS as necessary
- Long-term groundwater monitoring
- 5-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-5: Expansion 1 to Interim Response Action A

The major components are as follows:

- Removal of contaminated unconfined groundwater north of the RMA boundary in the First Creek and northern paleochannels using groundwater extraction wells
- Expansion 1 to IRA A (additional wells and trenches)
- Treatment of organic COCs present in the groundwater using carbon adsorption
- Recharge of treated groundwater using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring

- 5-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. N-6: Expansion 2 to Interim Response Action A

The major components are as follows:

Removal of contaminated unconfined groundwater north of the RMA boundary in the First Creek and northern paleochannels using groundwater extraction wells

- Expansion 2 to IRA A (additional wells and trenches)
- Treatment of the organic COCs present in the groundwater using carbon adsorption
- Recharge o[illegible]ed groundwater using wells and trenches
- Continued operation of the NBCS
- Improvements to the NBCS as necessary
- Long-term groundwater monitoring
- 5-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Northwest Plume Group Alternatives

After screening several extraction/recharge configurations, the following groundwater alternatives were developed for the Northwest Plume Group. The major components for each alternative are also listed.

Alternative NW-1: No Action

The major components are as follows:

- Long-term monitoring
- 5-year site review

This alternative was retained for the detailed analysis step as required by the NCP.

Common to the following alternatives are long-term groundwater monitoring and 5-year site reviews, as well as the Army's commitment to provide alternate water to any identified future users of groundwater exceeding PRGs (i.e., exposure control).

Alternative NW-2: Continued Operation of the Northwest Boundary Containment System with Improvements as Necessary

The major components are as follows:

- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- 5-year site reviews
- Exposure control

This alternative was retained for the detailed analysis step.

Alternative No. NW-3: Land Acquisition with Use Restrictions

The major components are as follows:

- Land acquisition
- Access and deed restrictions
- Continued operation of the NWBCS
- Improvements to the NWBCS as necessary
- Long-term groundwater monitoring
- 5-year site reviews
- Exposure control

This alternative was not retained for the detailed analysis step.

Alternative No. NW-4: Northwest Plume Groundwater Extraction/Recharge System

The major components are as follows:

- Removal of contaminated unconfined groundwater northwest of the RMA boundary using groundwater extraction wells

- **Treatment of organic COCs present in the groundwater using carbon adsorption**

- **Recharge of treated groundwater using trenches**

- **Continued operation of the NWBCS**

- **Improvements to the NWBCS as necessary**

- **Long-term groundwater monitoring**

- **5-year site reviews**

- **Exposure control**

This alternative was not retained for the detailed analysis step.

Detailed Analysis of Alternatives

The remaining alternatives (Alternative Nos. N-1, N-2, N-4, N-5, NW-1, and NW-2) were evaluated with respect to the threshold and primary balancing criteria required by the NCP. The criteria are listed below:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

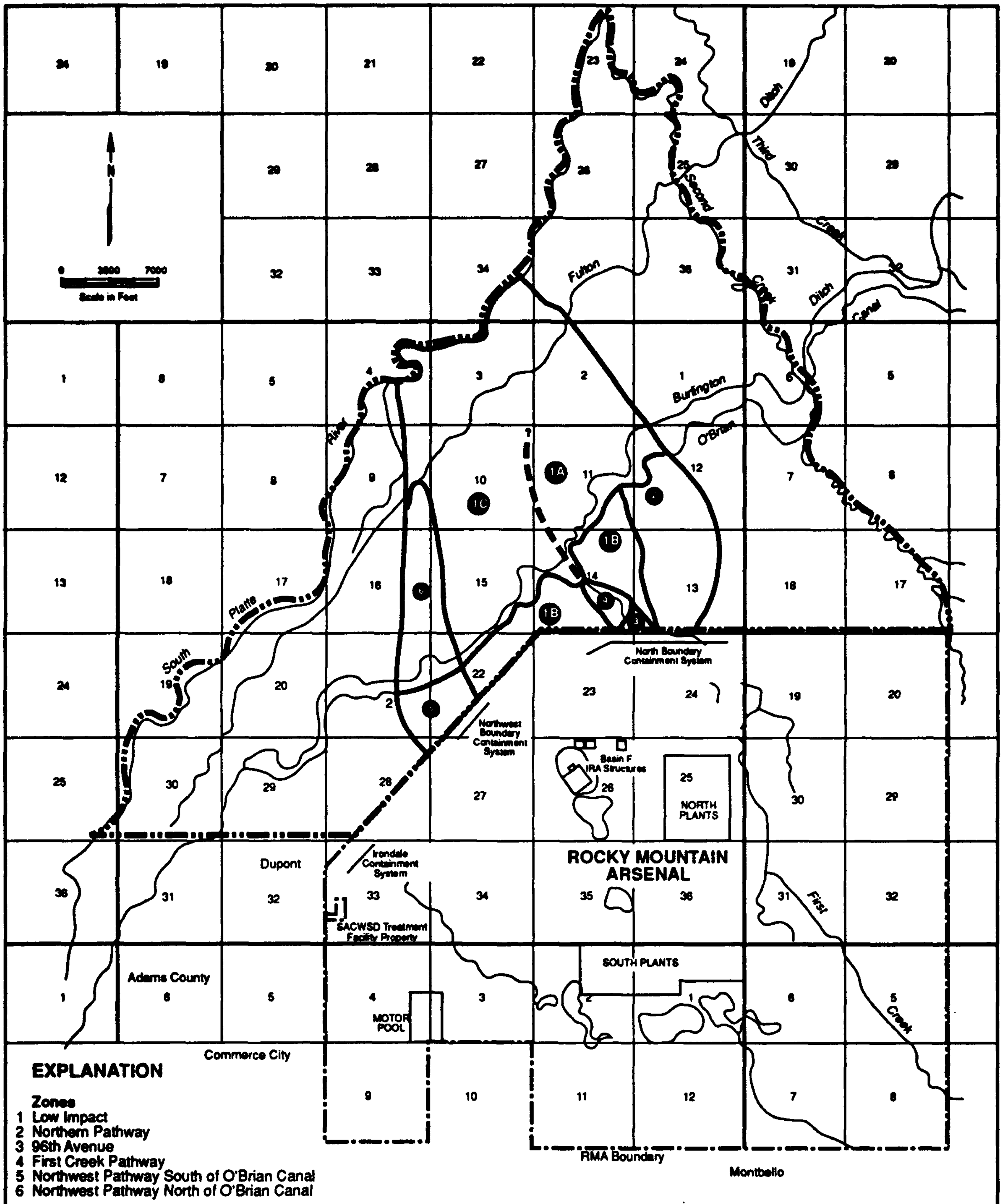
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

Evaluation of the modifying criteria (i.e., the state and community acceptance) is deferred until completion of the state and public comment periods.

A comparative analysis of the remedial alternatives identifying the relative advantages and disadvantages of each alternative was performed. Based on the analysis, a preferred site-wide alternative was selected.

Selection of the Preferred Site-wide Alternative

Using the evaluation of the alternatives with respect to the criteria required by CERCLA and the NCP, the preferred alternative was selected. The preferred site-wide alternative consists of Alternative No. N-4 (Interim Response Action A) for remediation of groundwater and surface water in the North Plume Group and Alternative No. NW-2 (Continued Operation of the NWBCS With Improvements as Necessary) for remediation of groundwater in the Northwest Plume Group.



Prepared for:
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Commerce City, Colorado

Figure ES1

OFFPOST OPERABLE UNIT
ENDANGERMENT ASSESSMENT ZONES

INTRODUCTION TO THE ENDANGERMENT ASSESSMENT/FEASIBILITY STUDY OFFPOST OPERABLE UNIT

This Revised Draft Final Endangerment Assessment/Feasibility Study (EA/FS) supersedes the Draft Final Offpost Operable Unit (OU) EA/FS, issued in March 1989.

The Revised Draft Final EA/FS report complies with guidelines prepared under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (Title 42, United States Code [USC], Sections 9601-9675), the Superfund Amendments and Reauthorization Act of 1986 (SARA), the revised National Contingency Plan (NCP) (Title 40, United States Code (USC) of Federal Regulations [CFR] Part 300), the regulations implementing the National Environmental Policy Act of 1969 (NEPA), and associated U.S. Environmental Protection Agency (EPA) guidance documents.

This introduction provides background information for the Offpost (OU) including setting, site history and land use, previous investigations, nature and extent of contaminants, and response actions for the Offpost OU.

SETTING

This section describes the site location, environmental setting, geology, and hydrogeology of the Offpost OU.

Site Location

The RMA National Priorities List (NPL) site is comprised of two OUs: Onpost and Offpost. As shown in Figure 1, the Onpost OU occupies 27 square miles in southern Adams County, Colorado, and lies north of the Denver metropolitan area and east of Commerce City, Colorado. The Offpost OU is defined as the area southeast of the South Platte River, north of 80th Avenue, southwest of Second Creek, and north of the north and northwest boundaries of RMA, as depicted in Figure 2. Additionally, the Offpost OU includes the surface waters of O'Brian Canal and Burlington Ditch as they extend northeast of Second Creek and the surface water of Barr Lake.

The Offpost OU encompasses rural residential, agricultural, and commercial/industrial areas located north and northwest of RMA.

<u>Environmental Setting</u>

The topography of the Offpost OU is similar to the topography onpost and consists of stream-valley lowlands separated by gently rolling uplands. The maximum local topographic relief in the area is about 300 feet. The elevation above mean sea level (MSL) ranges from approximately 5330 feet at the southern boundary of RMA to about 5030 at the South Platte River.

Cropland and rangeland provide habitat for numerous animal species, including game species such as cottontails, ring-necked pheasants, and mourning doves. Lake and wetland areas at Barr Lake provide feeding, breeding, and roosting areas for waterfowl and endangered species, including the bald eagle.

The climate of the offpost area is characterized by sunny, semiarid conditions. Approximately 37 percent of the total annual precipitation (16 inches) occurs in the spring, with much of this moisture falling as snow in the early spring. Summer is the hottest season and is characterized by scattered local thunderstorms during afternoons and evenings. Approximately 31 percent of the total annual precipitation occurs during the summer season. Winter is the coldest season, during which time approximately 13 percent of the total annual precipitation occurs.

The regional surface drainage is to the northeast toward the South Platte River. Surface water originating south of RMA, on RMA, or in the Offpost OU flows toward the South Platte River. Two major canals, O'Brian Canal and Burlington Ditch, and several smaller ditches flow from southwest to northeast between RMA and the South Platte River. O'Brian Canal receives some drainage from the Offpost OU and RMA where the canal intercepts First Creek. Burlington Ditch may receive surface water infrequently from First Creek.

Geology

Sediments at the land surface in the Offpost OU consist of unconsolidated alluvial and eolian deposits of Pleistocene and Holocene age. The composition of the unconsolidated sediments varies from clays to coarse gravels, and the thickness varies from less than 10 feet to approximately 100 feet. The thickest deposits of unconsolidated sediments occur in paleochannels eroded into the underlying Denver Formation.

The Denver Formation is of late Cretaceous to early Tertiary age, and consists of 250 to 300 feet of interbedded shale, claystone, siltstone, and sandstone, with a regional dip of one-half to one degree to the southeast. The uppermost bedrock unit was subjected to erosion before deposition of the overlying unconsolidated units. Paleochannels incised into the bedrock surface are present in many areas in the Offpost OU.

The presence of paleochannels in the Denver Formation surface has an impact on groundwater flow in the unconfined flow system (UFS). Two such paleochannels, the First Creek and northern paleochannels, are present north of the RMA North Boundary Containment System (NBCS). An additional paleochannel, the northwest paleochannel, is present west of the RMA Northwest Boundary Containment System (NWBCS). Coarse, unconsolidated materials commonly found within these paleochannels provide for preferential groundwater movement in the UFS. Groundwater contaminant plumes that have historically migrated across the RMA boundaries to the Offpost OU are generally confined to these paleochannels.

The Arapahoe Formation lies beneath the Denver Formation at depths of 230 to 300 feet at the RMA north boundary and has a regional dip of one-half to one degree to the southeast. The formation consists of 400 to 700 feet of interbedded conglomerate, sandstone, siltstone, and shale. The upper portion consists predominantly of 200 to 300 feet blue to gray shale with some conglomerate and sandstone beds. The lower portion consists largely of sandstone and conglomerate with less prevalent beds of shale. The lower portion is a source zone for many water supply wells in the area. The Arapahoe Formation is the oldest geologic unit present beneath the site that was investigated in the Offpost Remedial Investigation (RI) and Offpost RI Addendum programs.

Alluvial and eolian Pleistocene and Holocene deposits form much of the ground surface in the Offpost OU. At some locations, Denver Formation units crop out at the ground surface. The Arapahoe Formation is not present at the ground surface anywhere in the Offpost OU.

Hydrogeology

The two principal water-bearing units in the Offpost OU that have been impacted by chemicals originating from RMA are the unconsolidated alluvial deposits and the underlying Denver Formation. The hydraulic properties of these two units, including hydraulic conductivity, porosity, and associated groundwater flow velocities, are distinctly different. Hydraulically, these two units generally behave as distinct hydrostratigraphic units.

Groundwater flow in the Offpost OU area occurs within an UFS that overlies a confined flow system (CFS). The UFS includes groundwater present in the unconsolidated materials overlying the Denver Formation, the weathered upper portion of the Denver Formation, and, near the South Platte River, the weathered upper portion of the Arapahoe Formation.

The CFS includes the deeper portions of the Denver Formation and the underlying Arapahoe Formation. The Final Water RI (Ebasco, 1989), the Final Offpost RI (ESE, 1988a), and the Draft Final Offpost RI Addendum (Harding Lawson Associates [HLA], 1991a) reports provide further information concerning the conceptual model of groundwater flow in the unconfined and confined flow systems (UFS and CFS). On the basis of an evaluation of the distribution of contaminant plumes in the Offpost OU area, the UFS is considered the principal migration route for groundwater contaminants from onpost to the Offpost OU, although some contaminants are present in the CFS in the Denver Formation.

Water-level data for the UFS were collected from all Offpost OU monitoring wells during several monitoring events and programs. The UFS potentiometric surface slopes predominantly toward the northwest, indicating groundwater flow in that direction. This information is consistent with the interpretation that the South Platte River is a regional discharge point for the groundwater system in the Offpost OU. Hydraulic gradients in the Offpost OU range from 0.003 to 0.02 ft/ft and average approximately 0.004 to 0.005 ft/ft. The hydraulic gradients are highest

in the area immediately downgradient of the NBCS and in the vicinity of O'Brian Canal and Burlington Ditch.

The hydraulic gradient of the UFS near the canals is consistent with that reported in the Final Offpost RI. However, the hydraulic gradient near the NBCS has increased as a result of the installation and operation of recharge trenches in late 1988. Operation of these trenches has increased groundwater recharge in northern portions of Sections 23 and 24, near the northern RMA boundary.

The confined Denver Formation is heterogeneous and consists of interbedded claystones, siltstones, sandstones, and organic-rich (lignitic) intervals. Water-bearing layers of sandstone and siltstone occur in irregular beds dispersed within thick sequences of relatively impermeable material. Individual sandstone layers commonly are lens-shaped and range in thickness from a few inches to as much as 50 feet. Confined aquifer conditions are observed in sandstone layers within the deeper portions of the Denver Formation.

Water-level data collected from three Arapahoe Formation wells installed under the RI Addendum program indicate that the Arapahoe Formation is a confined aquifer. Data generally indicate that the Arapahoe Formation has a northerly to northwesterly regional groundwater flow direction, as presented in the Final Offpost RI.

SITE HISTORY AND LAND USE

This section presents a discussion of former RMA and Offpost OU activities and land uses.

Former Disposal Practices

RMA began operation in 1942. RMA was a site for the manufacture and demilitarization of chemical and incendiary munitions and the manufacture of industrial chemicals, primarily pesticides and herbicides, until 1984. A detailed account of disposal practices associated with these operations is presented in the Onpost Study Area Reports and RI Media Reports for each potential site.

From 1945 to 1950, RMA distilled available stocks of Levinstein mustard, demilitarized several million rounds of mustard-filled shells, and test-fired mortar rounds filled with smoke and high explosives. Also, many different types of obsolete World War (WW) II ordnance were destroyed by detonation or burning.

Colorado Fuel and Iron (CF&I) leased facilities at RMA in 1946. Julius Hyman & Company first leased facilities in 1947, and succeeded to the CF&I leasehold interest, with some modifications and additions in 1949. Shell Oil Company acquired a majority interest in Hyman in 1952, and operated the plant as the Julius Hyman Company until 1954, when the operation became the Shell Chemical Company - Denver Plant.

RMA was selected as the site for construction of a facility to produce Sarin, a nerve agent. The facility was completed in 1953, with the manufacturing operation continuing until 1957 and the munitions-filling operations continuing until late 1969. From 1970 until 1984, RMA was involved primarily with the disposal of chemical warfare material. This disposal included the incineration of TX anticrop agent and mustard agent explosive components, and the destruction of Sarin and related munitions casings by caustic neutralization.

Chemicals were introduced to the RMA environment primarily by the burial or surface disposal of solid wastes, discharge of wastewater to basins, and leakage of wastewater and industrial fluids from chemical and sanitary sewer systems. Munitions were destroyed and disposed of in trenches. Wastewater generated by the Army and private industry in the South Plants and North Plants areas was discharged to a series of unlined evaporation and holding basins (Basins A, B, C, D, and E) and to asphalt-lined Basin F at various times throughout the history of RMA operations.

The primary areas that have contributed to groundwater contamination at RMA include (1) former manufacturing facilities, (2) former waste storage basins, (3) solid waste disposal areas, (4) the chemical sewer system, and (5) locations with in the rail classification yard.

Land Use

The current land use within the Offpost OU is predominantly agricultural and rural residential with localized commercial/industrial land uses and open spaces. Areas within the Offpost OU are largely used for rangeland and dryland farming, with some rural residential areas and scattered areas of intensive agricultural use. Certain areas within the Offpost OU are currently zoned and developed for commercial/ industrial activities. Commerce City, which is located west of RMA, is the only urban area in the immediate vicinity of RMA and has recently annexed lands within the Offpost OU. Another geographic feature in the Offpost OU is Barr Lake, a state recreation area.

Farming in the Offpost OU ranges from large grain operations covering square miles to small subsistence farms to vegetable gardens. A number of these farms also maintain livestock. Subsistence and hobby farmers often consume a large part of their diet from locally produced vegetables and livestock produced in the Offpost OU.

Intentional application of pesticides for pest control purposes likely accounts for the presence of some concentrations of pesticides in Offpost OU soil. Many of the pesticides detected in Offpost OU soil are or have been commercially available and may have been applied agriculturally or residentially. These pesticides include cyclodiene compounds and chlorinated hydrocarbon insecticides.

The cyclodiene compounds aldrin, endrin, dieldrin, and isodrin detected in Offpost OU soil have been used as insecticides in areas similar to the Offpost OU from the 1940s to the mid-1970s. Aldrin was used in the early 1950s to protect cotton against boll weevils and in the 1970s for soil application in grain crops and termite control. In Colorado, dieldrin was used to control insects in field vegetable, grain, and fruit crops (Mullins, 1971) and against termites and locusts. Endrin was also used to control a wide range of pests. These insecticides were banned for general uses in 1975 by the EPA. Aldrin and dieldrin may still be used for certain restricted uses such as subsurface insertion for termite control and dipping of nonfood roots.

Evaluation of projected future land use at the Offpost OU indicates that areas of commercial/industrial and recreational land use will increase (Adams County Planning Commission, 1987). Rural residential (including agricultural) land use is expected to decrease in the Offpost OU.

PREVIOUS INVESTIGATIONS

As a result of the detection of chemicals in the Offpost OU, the Army initiated a regional sampling of hydrogeologic surveillance program requiring the quarterly collection and analysis of samples from more than 100 onpost and offpost wells and surface-water stations. This program was carried out under the direction of the RMA Contamination Control Program, established in 1974 to ensure compliance with federal and state environmental laws. The objectives of this program were to evaluate the nature and extent of contamination and to develop response actions to control chemical migration. Potential and actual chemical sources were assessed, and chemical migration pathways were evaluated. To minimize offpost discharge of RMA chemicals via groundwater, three boundary containment systems were constructed, one each at the northern, western, and northwestern boundaries of RMA. All three systems are currently in operation to intercept and treat contaminated groundwater and to recharge treated water.

From 1975 to the present, numerous groundwater monitoring programs have been conducted at RMA. The Army designed and implemented the 360 Degree Monitoring Program to monitor regional groundwater and surface water. The Army designed and implemented boundary system monitoring program to support the operation of the boundary control systems. Studies conducted at RMA to assess groundwater and surface-water conditions are discussed below.

The RMA Offpost Contamination Assessment Report (CAR) (ESE, 1987a) incorporated data from several studies to depict the distribution and concentrations of offpost contamination north and northwest of RMA. The scope of this investigation was intended to address critical data gaps required to evaluate a comprehensive set of multimedia exposure pathways. In the mid-1980s, the potential for contamination of private wells was investigated. These were referred to as Consumptive Use (CU) Studies, Phases I, II, and III. The CU Phase I and II studies (ESE, 1985; ESE

1986) addressed the RMA offpost area bounded to the south by East 80th Avenue, to the northwest by the South Platte River, and to the north and east by Second Creek.

In the CU Phase III study (ESE, 1987b), the Army conducted an inventory of privately owned drinking water wells in an area bound by East 80th Avenue on the south, East 96th Avenue on the north, the South Platte River on the west, and RMA on the east. The objectives of the study were as follows:

- Locate all shallow domestic wells (less than 100 feet) in the study area.
- Sample a representative number of the located wells.
- Assess the groundwater quality of the shallow alluvial aquifer.

U.S. Environmental Protection Agency Study Area

In 1981, a random national survey of drinking water systems was conducted by EPA. Several organic chemicals were detected in South Adams County Water and Sanitation District (SACWSD) wells. Additional sampling in 1982 and 1985 confirmed these results. As a result of these findings, EPA began an RI/FS of an area located west of RMA and south of the Offpost OU.

RMA was suspected as one of the potential sources of contaminants in the EPA study area because of the history of waste disposal practices on that site. In response, the Army and EPA built a water supply system for SACWSD. Further investigation by EPA's Field Investigation Team indicated that source areas other than RMA were contributing to groundwater contamination detected within the study area. Groundwater monitoring wells installed on the Chemical Sales Company (CSC) property have since confirmed CSC as a source of groundwater contamination.

Comprehensive Monitoring Program

In the mid-1980's, the Program Manager for RMA (PMRMA) developed the Comprehensive Monitoring Program (CMP), a long-term multimedia monitoring program designed to provide data

to facilitate evaluation of response actions. Sample collection under the CMP commenced in 1987, and data from the CMP were used in performing this EA/FS.

Scope of the Remedial Investigations

Based on known areas of onpost and offpost contamination and the predominant groundwater and surface-water flow patterns, the Offpost OU for the Offpost RI/FS is the area between north and northwest boundaries of RMA and the South Platte River. The specific boundaries of the unit are the same as for the Offpost CAR, as shown in Figure 2 and described below:

- Southeast boundary - north and northwest boundaries of RMA
- Southwest boundary - 80th Avenue
- West and northwest boundary - South Platte River
- Northeast boundary - Second Creek

The Offpost OU was originally selected on the basis of a conservative estimate of the area with which RMA chemicals may now or may eventually exist. However, based on current knowledge (HLA, 1991a), most of the Offpost OU is not contaminated by chemicals originating from RMA. The surface waters of Barr Lake have also been included in the Offpost OU because of the potential for contaminant migration through surface-water features.

Several sources of trichloroethene have been documented south of the Offpost OU in or near Commerce City. Also, recent investigations by EPA and the Army along the western sections of RMA have detected the presence of a trichloroethene plume entering Township 3S, Range 67W, Section 9 along the southern boundary of RMA. Although trichloroethene has been detected in selected dewatering wells of the Irondale system, no trichloroethene has been detected in the influent or effluent sumps of the system. Because of the potential for multiple trichlorethene sources upgradient of the Offpost OU, trichloroethene detected in the area between 80th and 88th Avenues falls under the jurisdiction of EPA.

The primary objectives of the Offpost RI were to:

- Collect additional data to refine the current understanding of groundwater flow and surface-water patterns, and the nature and extent of contaminants offpost of RMA.

- Evaluate the potential for chemical migration to the Offpost OU in various media, such as groundwater, surface water, sediment, air, and biota.

The review of past studies provided the data to evaluate wells that have been sampled in the past, use results from previous aquifer tests, to analyze historical onpost and offpost contaminant plumes, and to examine and develop an overall geologic and hydrologic understanding of the Offpost OU. Additionally, biota and air quality information for the Offpost OU were reviewed and used to assess the human and environmental receptors that may be at risk and to define airborne pollutant pathways.

As a result of the review of the past programs and the original Offpost RI program, limitations to the groundwater, soil, surface water, sediment, and biota databases were identified, and appropriate sampling and analysis were completed in the RI Addendum (HLA, 1991g) program. Data collection consisted of compiling new hydrogeologic and chemical data relevant to the Offpost OU. Data were obtained by drilling new wells and borings, collecting groundwater and surface-water samplers for analysis, measuring groundwater levels and surface-water flows, conducting aquifer tests, and obtaining sediment samples for analysis.

Surface-water and sediment samples were collected in the Offpost OU to define chemicals in the media. Samples were collected from streams, creeks, impoundments, and lakes that were suspected pathways for migration of onpost contamination to the Offpost OU. The data were used to evaluate contamination in surface water and sediment as well as to evaluate surface water and groundwater interaction.

Biota and air-quality condition were evaluated using onpost and offpost information collected during past and current studies. Input from the Offpost CAR was used to assess transport of chemicals and impacts on biota in the Offpost OU from onpost conditions. Data from the Air RI Report (ESE, 1988b) were used to assess the potential for migration of airborne chemicals to the Offpost OU.

The water, sediment, biota, and air quality information was organized so that a comprehensive evaluation of RMA chemicals in all media could be made in the Offpost OU. The

information collected during the Offpost RI and RI Addendum was integrated with historical data as well as data being collected during other ongoing RMA investigations.

In general, the RI Addendum summarizes new information primarily pertaining to further assessment of the extent of contamination in various media (groundwater, soil, surface water, sediment, and biota) within specific geographic areas. Activities performed in preparation of the RI Addendum include a review of existing data and collection and interpretation of additional field data to address identified data needs.

NATURE AND EXTENT OF CONTAMINATION

This section discusses the nature and extent of contaminants in the groundwater, soil, surface water, sediment, and air media in the Offpost OU as currently understood. The Offpost RI and RI Addendum reports were the primary sources of information for the groundwater, soil, surface water, sediment, and biota media. Another source of information for the groundwater medium was CMP annual groundwater data. The primary source of information on the air medium was the CMP Air Quality Data Assessment Report for 1989 (RLSA, 1990). In determining COCs and exposure point concentrations, the EA used environmental data for the period 1985 to 1991 including these reports.

Groundwater - Semivolatile Organic Compounds

This section provides a summary of the nature and extent of contamination in groundwater in the Offpost OU on the basis of groundwater occurrence in both the UFS and CFS. Diisopropylmethylphosphonate (DIMP), dicyclopentadiene, dieldrin, and endrin are the most widespread and consistently detected semivolatile organic compounds (SVOCs) in groundwater in the Offpost OU.

The most widespread contaminant detected in groundwater in the Offpost OU is DIMP. As Figure 3 illustrates, DIMP is distributed in a continuous plume extending from the RMA north and northwest boundaries to the South Platte River. Samples from 89 monitoring wells were analyzed for DIMP, which DIMP was above the CRL in 71 of these samples. In general, the

highest concentrations of DIMP offpost occur between the RMA northern boundary and the O'Brian Canal. The highest observed concentrations were 5800 micrograms per liter (μg/l) in the First Creek paleochannel, 860 μg/l in the northern paleochannel, and 80 μg/l in the northwest paleochannel.

Current data indicate the distribution of dicyclopentadiene, as shown in Figure 4, is generally limited to the First Creek paleochannel. The maximum concentrations of dicyclopentadiene reported in the Offpost RI Addendum was 600 μg/l.

The distribution of dieldrin is shown in Figure 5. Dieldrin occurs in the Offpost OU north of the northern and northwestern RMA boundaries. The highest concentrations of dieldrin are found in wells located in the First Creek paleochannel, ranging from 0.6 to 0.9 μg/l. Dieldrin plumes are also interpreted in limited areas in the northern paleochannel and in two areas north of the northwestern RMA boundary. Detectable concentrations of dieldrin in the northern paleochannel and northwestern paleochannel ranged from 0.05 to 0.14 μg/l.

The distribution of endrin is shown in Figure 6. The highest concentrations of endrin ranged from approximately 0.25 to 0.75 μg/l for wells immediately north of the northern RMA boundary. The maximum concentration of endrin was 0.748 μg/l from well 37309, located approximately 1500 feet north of RMA. Endrin was also detected in groundwater samples collected from wells in the central portion of the northern paleochannel.

Other SVOCs were detected in groundwater samples from the Offpost OU. The other SVOCs detected include the nitrogen phosphorous pesticides atrazine, malathion, and parathion; the organsulfur compounds 4-chlorophenylmethyl sulfide ($CPMSO_2$) and 4-chlorophenylmethyl sulfoxide (CPMSO); and the organchlorine pesticides aldrin, isodrin, chlordane, 2,2-bis (para-chlorophenyl)-1,1-dichloroethene (DDE), and 2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane (DDT).

The distribution of atrazine in the Offpost OU is similar to that of the organochlorine pesticides (OCPs). Atrazine was detected in 21 Offpost OU wells, with the maximum concentrations occurring in the First Creek (46.0 μg/l) and northern (72.9 μg/l) paleochannels. Atrazine

was generally not detected in groundwater samples collected from the Offpost OU off the northwestern RMA boundary, except for two isolated occurrences.

Although CPMSO and $CPMSO_2$ are both organosulfur compounds, their distributions in offpost groundwater differ. CPMSO was generally only found in samples collected from wells installed in the northern paleochannel, whereas $CPMSO_2$ was generally only found in samples collected from wells located in the First Creek paleochannel. CPMSO was generally found at levels higher than those reported from $CPMSO_2$. CPMSO was detected at concentrations up to 82.2 μg/l in the northern paleochannel. $CPMSO_2$ was also detected in the First Creek paleochannel at concentrations up to 21.0 μg/l.

The distribution of the additional OCPs (aldrin, isodrin, chlordane, DDE, and DDT) is similar to the previously discussed distribution of the OCPs dieldrin and endrin. The maximum concentrations of these compounds generally occur in the First Creek paleochannel, usually in the area 500 to 1000 feet north of the NBCS. Generally, only sporadic, isolated occurrences of these compounds were observed in the Offpost OU north of the RMA northwestern boundary.

Groundwater - Volatile Organic Compounds

The volatile organic compounds (VOC) most frequently detected in the Offpost OU include chloroform, chlorobenzene, dibromochloropropane, tetrachloroethene, trichloroethene, 1,2-dichloroethene, carbon tetrachloride, and benzene.

Chloroform occurs primarily downgradient of the NWBCS and in the northern paleochannel, as shown in Figure 7. Chloroform was generally not found in the First Creek paleochannel. Concentrations of chloroform emanating from the northern RMA boundary are higher than concentrations in the Offpost OU north of the northwestern RMA boundary. The highest concentrations of chloroform occur at the north end of the northern paleochannel (200 to 400 μg/l). The highest concentration of chloroform was 19.8 μg/l in the northwestern paleochannel.

The distribution of chlorobenzene is presented in Figure 8. The plumes are confined to localized portions of the First Creek and northern paleochannels. The maximum concentration of

chlorobenzene was 38.2 μg/l in a groundwater sample collected from a well located in the northern paleochannel approximately one mile north of RMA. The maximum reported concentration in the First Creek paleochannel is less than 2 μg/l.

The distribution of dibromochloropropane is shown in Figure 9. As shown in Figure 9, dibromochloropropane was generally only found in samples from wells in the northern paleochannel. A few isolated occurrences of dibromochloropropane were observed in the First Creek paleochannel and immediately downgradient of the O'Brian Canal near the northern end of the northern paleochannel. The maximum concentrations of dibromochloropropane ranged from approximately 2 to 7 μg/l in a few wells located in the northern paleochannel. All other detectable levels of dibromochloropropane were less than 1 μg/l.

The distribution of trichloroethene and tetrachloroethene is presented in Figures 10 and 11, respectively. These VOCs are found in the First Creek and northern paleochannels. The highest concentrations of these compounds were detected in samples collected from wells located at the northern end of the northern paleochannel. The concentrations of tetrachloroethane are higher than those reported for trichloroethene. The maximum concentrations of tetrachloroethane were approximately 100 μg/l in two wells located in the northern paleochannel, approximately one-mile north of the RMA boundary. The highest concentrations of trichloroethene in the Offpost OU north of RMA ranged from approximately 5 to 7 μg/l.

Other volatile organic compounds (VOCs) detected in the Offpost OU include benzene, carbon tetrachloride, 1,1,1-tetrachloroethane, 1,1-dichloroethane, 1,2-dichloroethene, toluene, and xylenes. These compounds were generally found in only a few groundwater samples collected from wells installed in the UFS.

Groundwater - Inorganic Compounds

This section describes the distribution of selected inorganic constituents in groundwater. The inorganics presented below include arsenic, chloride, fluoride, and mercury.

The distribution of arsenic based on data collected in support of the Offpost RI Addendum and for the CMP, is shown in Figure 12. As shown in Figure 12, the distribution of arsenic is

sporadic, with detectable levels of arsenic occurring in a number of areas. Arsenic occurs in a plume along the First Creek paleochannel. The maximum concentrations of arsenic in the Offpost OU are 4 to 5 μg/l.

The distribution of chloride is shown in Figure 13. Chloride occurs in plumes in the Offpost OU north of the northern and northwestern RMA boundaries. Chloride concentrations in the First Creek and northern paleochannels generally exceed 250,000 μg/l. The maximum concentrations of chloride occur in the First Creek paleochannel. Offpost of the northwestern RMA boundary, chloride concentrations exceeding 250,000 μg/l occur immediately downgradient of the RMA boundary. Concentrations of chloride below 50,000 μg/l occur only in limited areas (Figure 13).

The distribution of fluoride is presented in Figure 14. Fluoride concentrations generally exceed 3000 μg/l in the First Creek paleochannel and 2200 μg/l in the northern paleochannel. Concentrations average approximately 2000 μg/l in the northwestern paleochannel.

The Final Offpost RI reported mercury in only one offpost groundwater sample. The sample, which was collected from well 37342 located in the First Creek paleochannel, had a mercury concentration of 0.36 μg/l. Data generated during Offpost RI Addendum activities showed detectable levels of mercury in four samples collected from wells located 2000 to 7000 feet offpost of the northwestern RMA boundary. Mercury concentrations in these wells ranged from 0.210 μg/l to 1.64 μg/l. The distribution of these sampling locations does not suggest a mercury plume in the Offpost OU, and detections are considered sporadic. Additionally, data collected under the Fall 1989 CMP show a higher frequency of detection for mercury than reported in the Final Offpost RI. The FY90 CMP reported that field or laboratory contamination existed for those mercury results. Thus, data for mercury are considered questionable and not representative of actual groundwater conditions.

<u>Nature and Extent of Confined Denver Formation Contamination</u>

The data and interpretations presented in this section are for groundwater samples collected from 14 offpost confined Denver Formation wells in the Offpost OU. Figure 15 presents the

locations of these wells. Additional information concerning the confined Denver Formation groundwater is presented in Section 3.3.2 of the Final Offpost RI report.

Data were examined from the Fall 1989 and Spring 1991 CMP sampling rounds, which represent the two most recent sampling rounds. The data reported detections of the following organic compounds: benzene, chlorobenzene, chloroform, DIMP, dibromochloropropane, phenol, and 1,1,1-trichloroethane. The most frequently detected compounds were DIMP, chloroform, and chlorobenzene. In general, the detections were not consistent from one sampling event to the next for the same well. DIMP was detected most frequently; however, detections occurred in only 11 sampling events out of 42 sampling events. The concentrations of DIMP ranged from 0.443 μg/l to 46.0 μg/l. Chloroform and chlorobenzene detection frequencies were below 10 percent. Chloroform concentrations ranged from 0.631 μg/l to 1.30 μg/l. Chlorobenzene detections ranged from 1.10 μg/l to 51.5 μg/l.

The observed detections indicate sporadic, isolated low-level occurrences of these compounds in the Offpost OU in the confined Denver Formation. The data are not consistent temporally for the same well and do not indicate a spatial or areal trend indicative of a contaminant plume.

Nature and Extent of Confined Arapahoe Formation Contamination

Two isolated detections of DIMP and one of chloroform were observed in approximately 30 Arapahoe Formation wells sampled by the Army. The detections do not appear to be representative of overall aquifer conditions. For example, the majority of samples collected from Arapahoe Formation wells did not contain detectable concentrations of organic compounds. In addition, DIMP and chloroform were not detected consistently from one sampling event to the next.

Surface Soil

This section presents the concentrations and distributions of compounds detected in soil in the Offpost OU. As shown in Figure 16, the organochlorine pesticides (OCPs) DDT, DDE, aldrin,

chlordane, dieldrin, endrin, hexachlorocyclopentadiene, and isodrin were detected above Certified Reporting Limits (CRLs) in surficial soil collected in the Offpost OU. The most widespread and frequently detected OCP was dieldrin. Concentrations of dieldrin detected in samples in the Offpost OU ranged from 2.20 to 250 micrograms per kilogram (μg/kg). DDT, aldrin, endrin, and DDE were also frequently detected, generally in samples where dieldrin was also detected.

Offpost OU suface soil was contaminated by the deposition of airborne contaminants and non-RMA-related intentional agricultural application of pesticides and irrigation practices.

The greatest number of compounds and highest concentrations were observed north of RMA, with a few occurrences to the east and west of RMA. Several reasons may, in part, explain the presence of these compounds north and west of the canals: (1) several of the compounds detected in the surficial soil are or have been available commercially and may have been applied agriculturally or residentially and (2) some areas where samples were collected may have been previously irrigated with surface water and/or groundwater originating from RMA.

Arsenic was detected in approximately 20 percent of the samples at concentrations ranging from 2.61 to 4.62 micrograms per gram (μg/g). The distribution of arsenic was limited to the following detection areas:

- East of RMA
- Immediately north of RMA
- West of the northwest boundary
- Along Burlington Ditch

No identifiable pattern to the distribution is evident.

Mercury was detected in approximately 10 percent of the samples at concentrations ranging from 0.0719 μg/g to 0.325 μg/g. A discernable pattern to the distribution of mercury is not evident.

The concentrations of arsenic and mercury in soil were not statistically evaluated above background as presented in the Offpost EA (Volume II, Section 1.0).

Subsurface Soil

Six subsurface soil samples were collected in the 96th Avenue residential area and analyzed for OCPs, arsenic, and mercury. Only one detection of OCPs was reported in subsurface soil samples. Dieldrin was detected at a concentration of 7.0 $\mu g/kg$ in a sample collected between 0 and 1 foot. Arsenic was detected above the CRL in one subsurface soil sample at a concentration of 3.59 $\mu g/g$ in a sample collected between 0 and 1 foot. Mercury was not detected above the CRL in any subsurface soil samples.

Surface Water

Figure 17 presents the distribution of organic contaminants detected in Offpost OU surface water as presented in the Offpost RI Addendum. The concentrations of organic compounds detected in offpost surface-water samples typically have been highest in First Creek near the O'Brian Canal.

DIMP was the organic compound most frequently detected in surface water in the Offpost OU. DIMP was also the most widely distributed compound and was detected in surface-water samples collected from First Creek, O'Brian Canal, and Burlington Ditch at concentrations ranging from 0.532 $\mu g/l$ to 59.0 $\mu g/l$.

The greatest number and highest concentrations of detected OCPs occur in the reach of First Creek between the northern RMA boundary and the confluence with O'Brian Canal.

The maximum detections of arsenic and several other inorganic constituents including chloride and sulfate were found in samples collected from First Creek along the reach between the RMA boundary and the First Creek confluence with O'Brian Canal. Arsenic was detected at concentrations ranging from 2.78 to 280 $\mu g/l$ in Offpost RI Addendum samples. The concentration of 280 $\mu g/l$ is considered anomalous and not representative of surface-water quality in the Offpost OU. The maximum concentrations of arsenic are commonly found in surface-water samples collected from First Creek immediately downstream of the onpost sewage treatment plant. Arsenic concentrations of approximately 70 $\mu g/l$ have been detected at this location (RSLA, 1990).

Groundwater and surface-water interaction is known to occur in the reach of First Creek between the northern RMA boundary and the confluence of First Creek with O'Brian Canal. This interaction has been discussed and documented in the Final Offpost RI and FY90 Surface Water CMP. Comparison of the concentrations of organic compounds detected in surface-water samples with those detected in groundwater samples collected in the vicinity of this reach of First Creek supports the conclusion that contaminated groundwater discharging into First Creek may be the source of organic contamination in surface water. The decrease in number and concentrations of organic compounds in Burlington Ditch and the O'Brian Canal indicates that dilution of surface water by the ditch and canal is occurring. The distribution of arsenic in offpost surface water suggests a source other than groundwater. A potential source appears to be onpost Sewage Treatment Plant discharge to First Creek.

Sediment

Figure 18 presents the distribution of organic contaminants detected in sediment as presented in the Offpost RI Addendum. The following organic compounds had the highest frequency of detection in sediment samples in the Offpost OU: aldrin, chlordane, dieldrin, and dibromochloropropane. The detections were predominantly in samples collected from in First Creek and were generally low concentrations.

Arsenic and mercury were detected at low concentration levels in sediment samples in the Offpost OU. Mercury was detected only in the Burlington Ditch, O'Brian Canal, and Barr Lake samples. Arsenic was detected in sediment samples in the Offpost OU from all water bodies sampled.

Air

Results from onpost RMA air monitoring during 1988 and reported in the FY88 Air CMP indicated that total suspended particulate (TSP) levels at RMA boundaries were below the levels of metropolitan Denver. Asbestos was monitored but not detected. VOCs measured at RMA boundaries appear to present toxic risks similar to those encountered in the urban environment of

metropolitan Denver. Levels of SVOCs were detected at negligible and/or regional baseline levels at RMA boundaries. Metal levels were proportional to TSP concentrations and were not elevated.

GROUNDWATER TREATMENT SYSTEMS THAT AFFECT THE OFFPOST OPERABLE UNIT

Three major containment/treatment systems, the Irondale Containment System (ICS), the NBCS, and the NWBCS, have been installed at the RMA boundaries to control the migration of contaminants to offpost areas. All three of the systems are currently in operation to intercept and treat contaminated groundwater and to recharge the treated water. In addition to the boundary control systems, a groundwater intercept and treatment system north of RMA (Groundwater Intercept and Treatment System North of RMA Interim Response Action A [IRA A]) is currently being constructed to provide remediation of alluvial groundwater in the Offpost OU.

Irondale Containment System

The ICS is located at the southern end of the RMA northwest boundary within Section 33 and consists of a hydraulic control system and a carbon treatment system. The ICS became operational in 1981. The majority of the area downgradient of the ICS is contained within the EPA offpost study area, although portions of the downgradient area are within the confines of the Offpost OU. A review of monitoring data downgradient of the ICS shows contaminant concentrations to be low and probably attributable to the source of contamination within the EPA offpost study area rather than RMA. Therefore, the configuration, operation, and performance of the ICS are not relevant to this study and will not be discussed further.

North Boundary Containment System

The NBCS is located just south of the RMA north boundary in Sections 23 and 24. The NBCS consists of a system of dewatering wells with contaminated groundwater from the unconfined flow system, a soil-bentonite barrier to separate contaminated and treated groundwater and to impede offpost migration of contaminated groundwater, a carbon-adsorption

treatment system to remove organic contaminants, and a system of recharge wells and trenches to return treated groundwater to the UFS.

The NBCS was constructed in two phases during 1978 and 1981. Initially a pilot system was installed and became operational in 1978. The pilot system was expanded approximately 1400 feet to the west and 3840 feet to the east in 1981. Recharge trenches were added to the west end of the system in 1988. Additional recharge trenches were added to the east end of the system in 1990. Currently, the soil-bentonite barrier is 6740 feet long and approximately 3 feet wide, with a designed hydraulic conductivity of 1×10^{-7} centimeters per second (cm/sec) or less. The barrier depth varies from 20 feet at the western end to over 40 feet along the eastern extension. The barrier is anchored in the Denver Formation.

Currently, the average flow through the NBCS treatment system is approximately 240 to 250 gallons per minute (gpm) according to the Final Implementation Document for IRA A (HLA, 1991b). All water is treated and recharged to the alluvial portion of the UFS.

Examination of groundwater contaminant distribution patterns indicates that the NBCS is having a significant effect on the distribution of organic compounds in the Offpost OU. The NBCS treatment plant is effectively removing the organic contaminants for which it was designed. Concentrations of organic contaminants above CRLs have not generally been detected in the system effluent. Inorganic contaminants such as chloride and fluoride are not being treated.

Northwest Boundary Containment System

The NWBCS is located along the northwest boundary of RMA in the southeast quarter of Section 22. Construction of the NWBCS began in 1983, and the system became operational in 1984. The purpose of this system was to intercept and remove dibromochloropropane and other organic compounds from a plume of contaminated groundwater originating onpost.

Contaminant bypass was observed at the northeast end of the system in 1988. Recharge was increased at the northeast end in December 1988 to prevent continued contaminant bypass. The system consists of a line of 15 upgradient dewatering wells, a soil bentonite barrier extending approximately two-thirds of the length of the dewatering system, 21 downgradient recharge wells,

and a carbon-adsorption treatment facility. Groundwater is pumped from the dewatering wells on the upgradient side of the barrier, treated by carbon adsorption, and returned to the aquifer through recharge wells near the RMA boundary.

An IRA to improve the NWBCS was initiated in 1989. In April 1990, the NWBCS Improvements IRA B(ii) was divided into two phases: NWBCS Short-Term Improvements IRA and NWBCS Long-Term Improvements IRA. The long-term improvements involve a more thorough assessment of the NWBCS and the short-term improvements.

Under the NWBCS Short-Term Improvements IRA, the existing groundwater intercept system was extended both to the southwest and northeast. The soil-bentonite wall was extended across the alluvial channel found northeast of the system to prevent contaminant bypass. Additional extraction wells were added to the existing system to intercept and treat the water in this channel. The northeast extension was completed in July 1990, and recharge rates at the northeast end of the system were reduced. Higher recharge rates resumed in July 1991 at the northeast end of the system. New extraction wells and recharge wells were added to the southwest end of the system and became operational in August 1991.

Interim Response Action A

IRA A addresses contaminant migration north of RMA along two primary contaminant pathways, defined by the First Creek and northern paleochannels.

In the area north of the RMA north boundary, IRA A is being implemented for remediation of contamination in alluvial groundwater in the First Creek and no ɔaleochannels. The system has been designed to intercept and extract contaminated groundwater from the UFS in each paleochannel, treat the organic fraction of the groundwater, and recharge treated water to the UFS. Groundwater extraction will be achieved by installing and operating well systems. Water will be treated using a granular activated carbon adsorption system and will be recharged to the UFS using a combination of wells and trenches.

The IRA was designed to be flexible to be compatible with the final remedy. Compatibility with the final remedy could be achieved by modifying the system to include the addition of new

wells, treatment processes, or additional treatment capacity if necessary. Construction of IRA A began in November 1991.

The groundwater treatment system for IRA A is designed to treat a maximum flow of 720 gpm and an average initial flow of 480 gpm; however, the facilities will be able to accommodate flows less than the average, with a minimum flow of 200 gpm.

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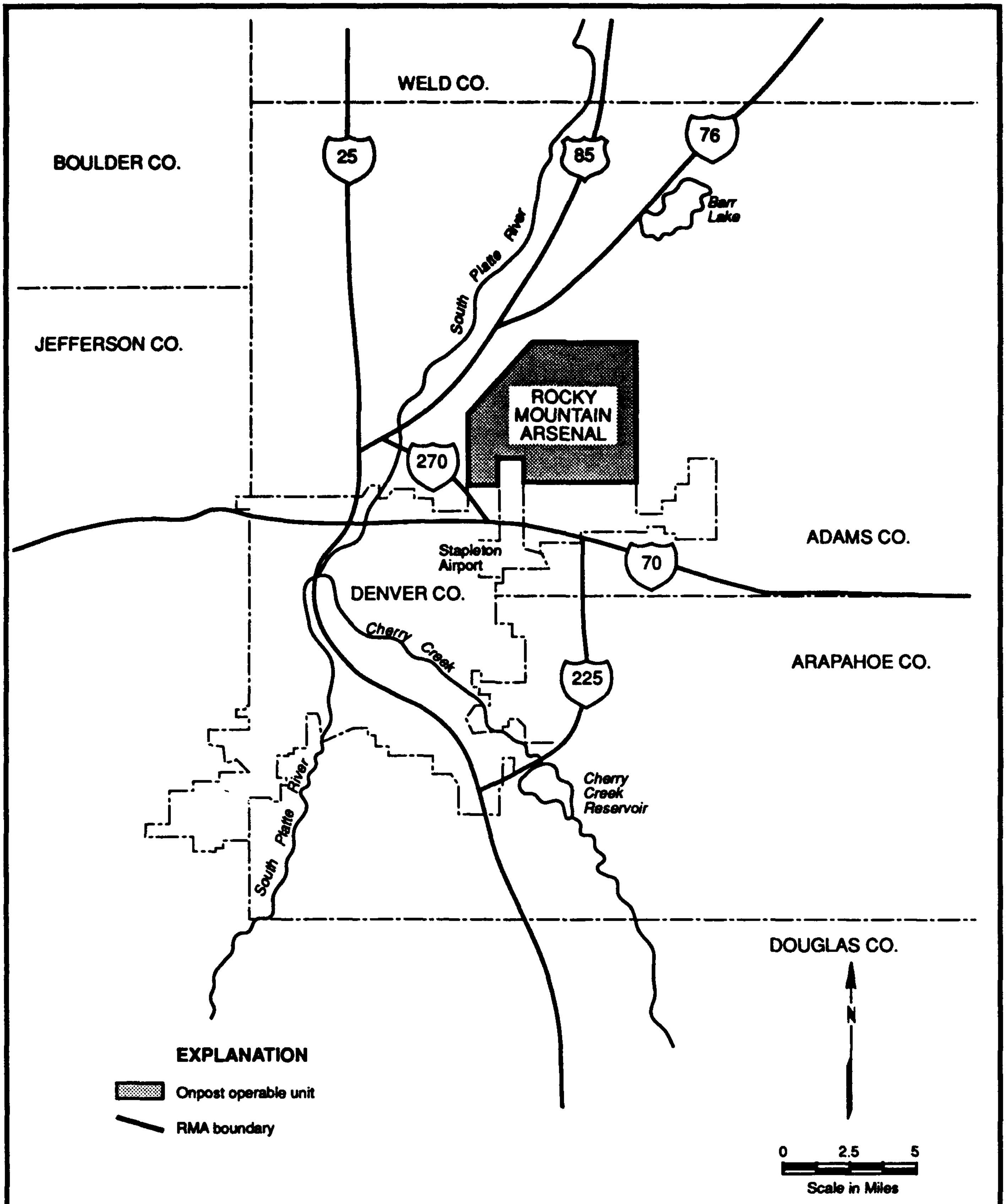
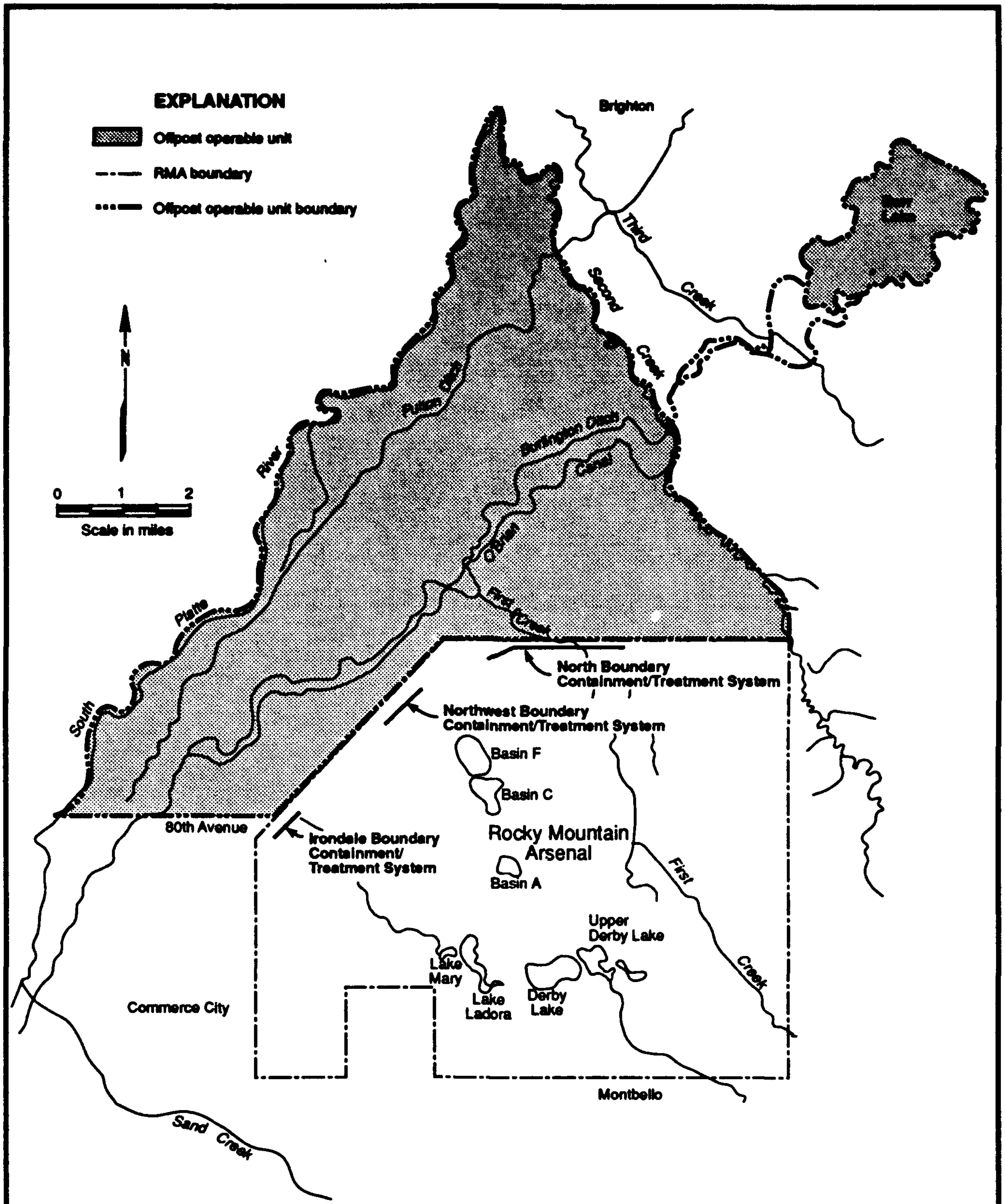


Prepared for: Program Manager for Rocky Mountain Arsenal Commerce City, Colorado	Figure 1 LOCATION MAP OF ONPOST OPERABLE UNIT, ROCKY MOUNTAIN ARSENAL

RMA1 1101



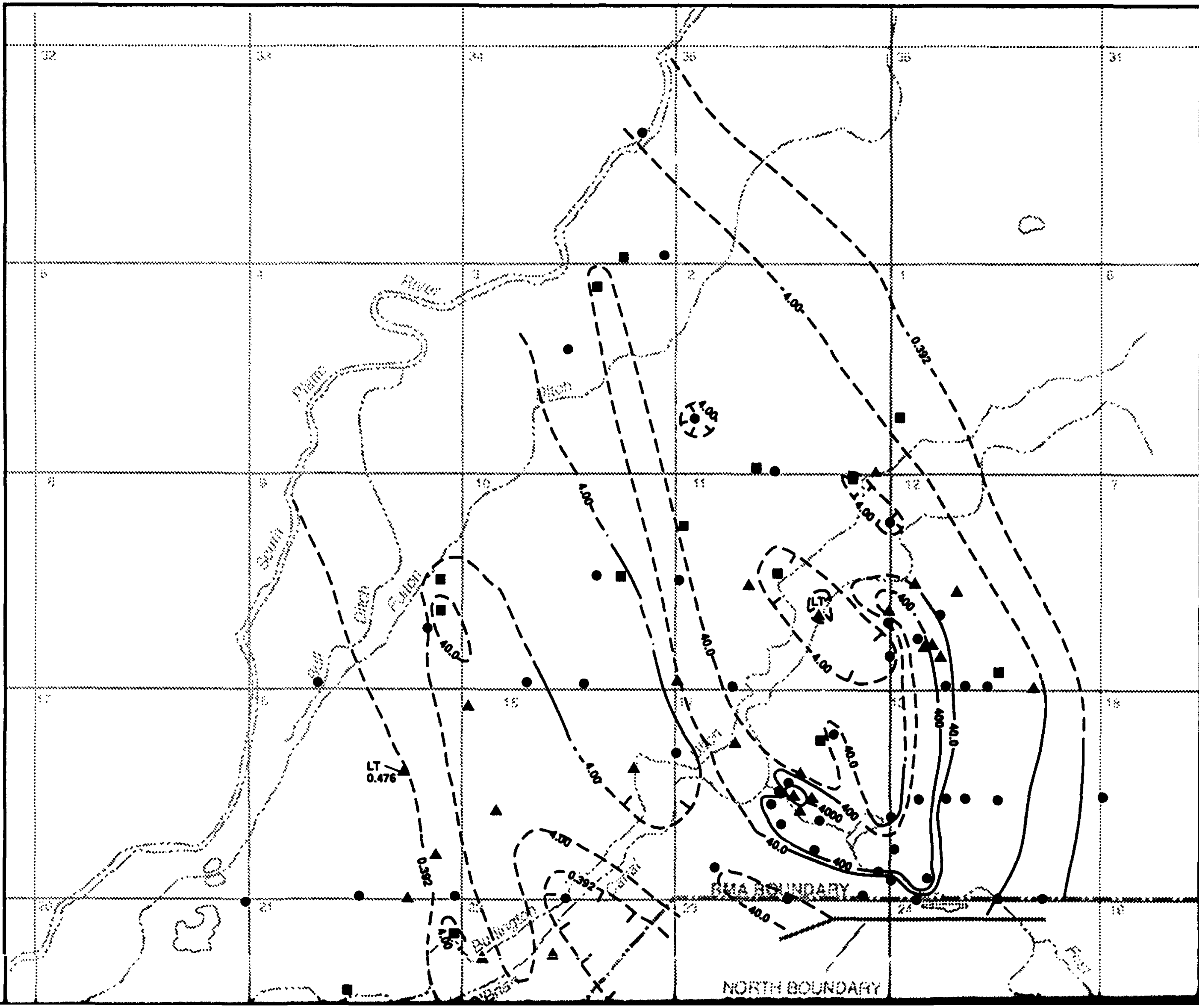
Prepared for:
Program Manager for
Rocky Mountain Arsenal

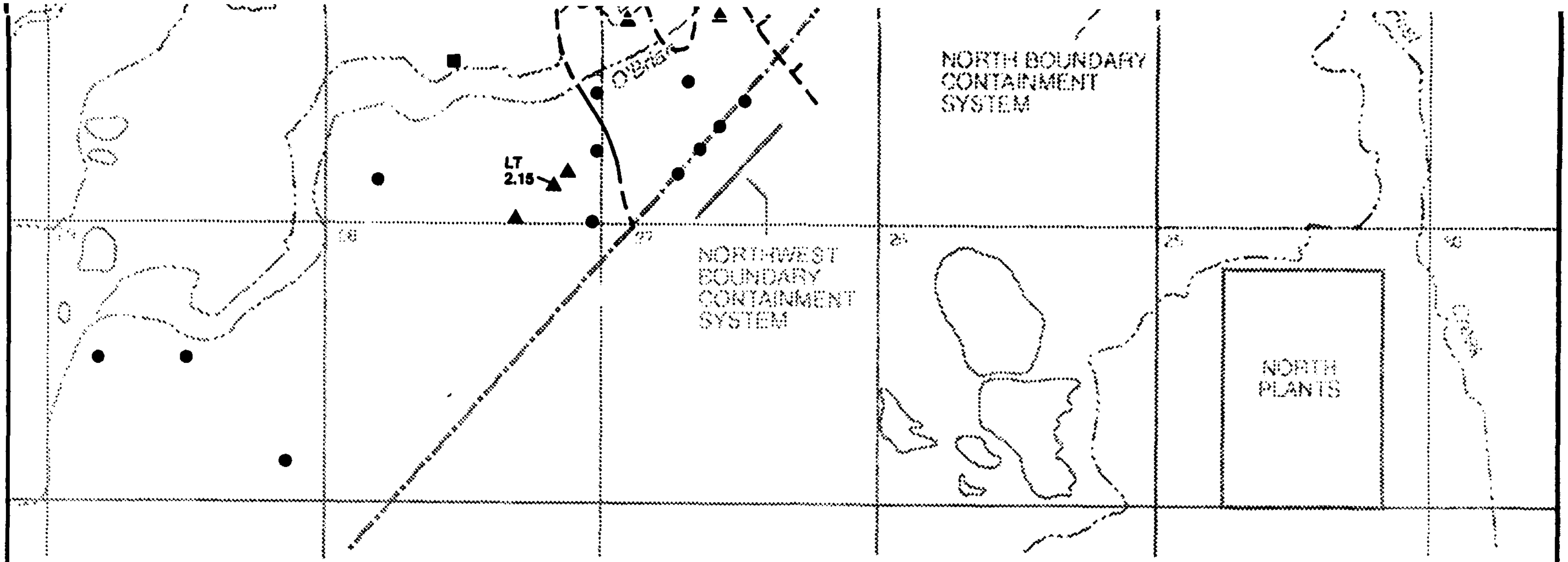
Commerce City, Colorado

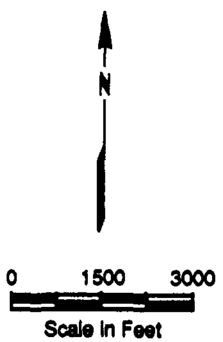
Figure 2

OFFPOST OPERABLE UNIT,
ROCKY MOUNTAIN ARSENAL

RMA1 1144


0.392
4.00
40.0
400
4000
LT
LT 0.476
RMA BOUNDARY
NORTH BOUNDARY
South Platte River
Fulton Ditch
Burlington Canal
First





EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 / LT — Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.392
4.00
40.0
400
4000

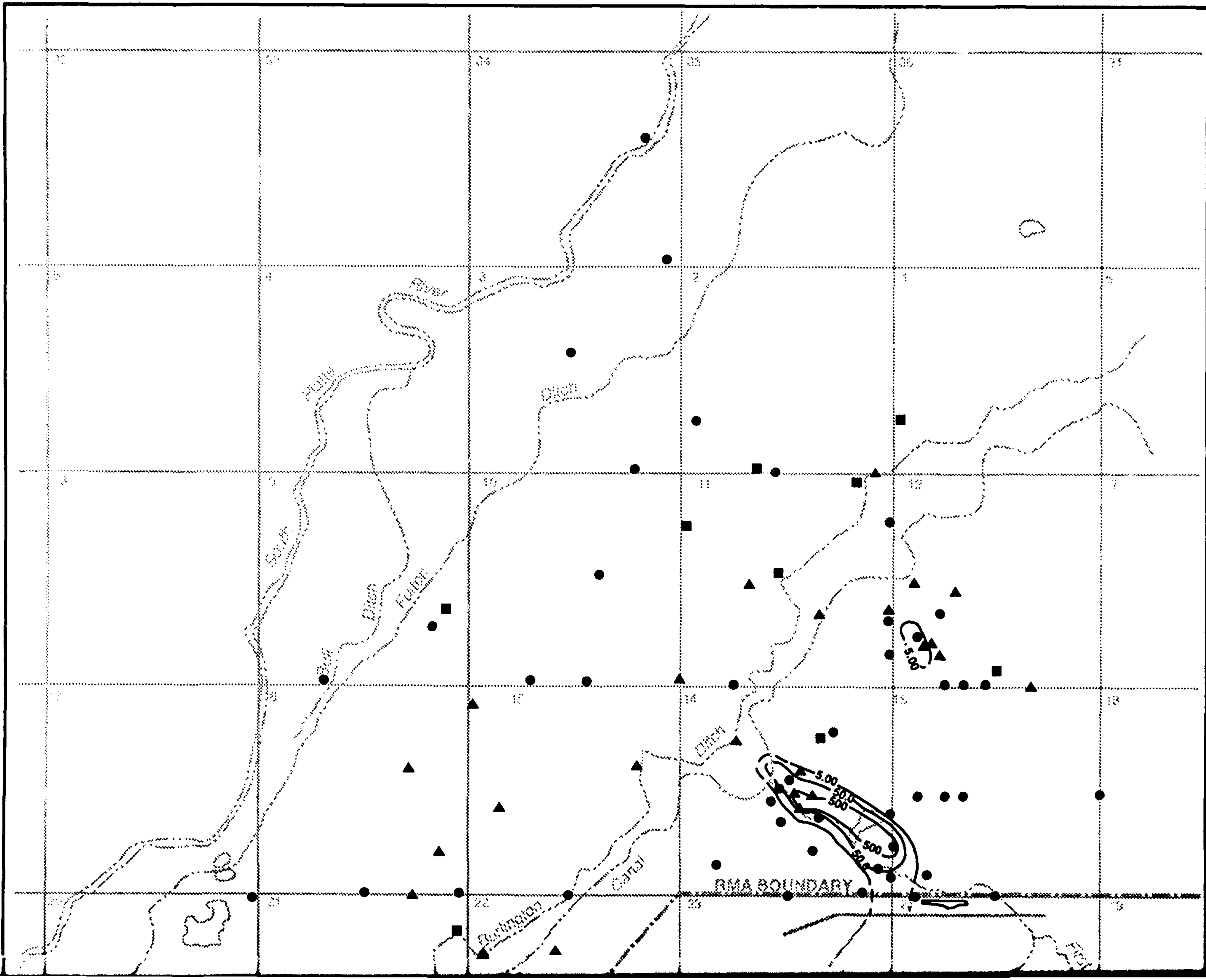
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

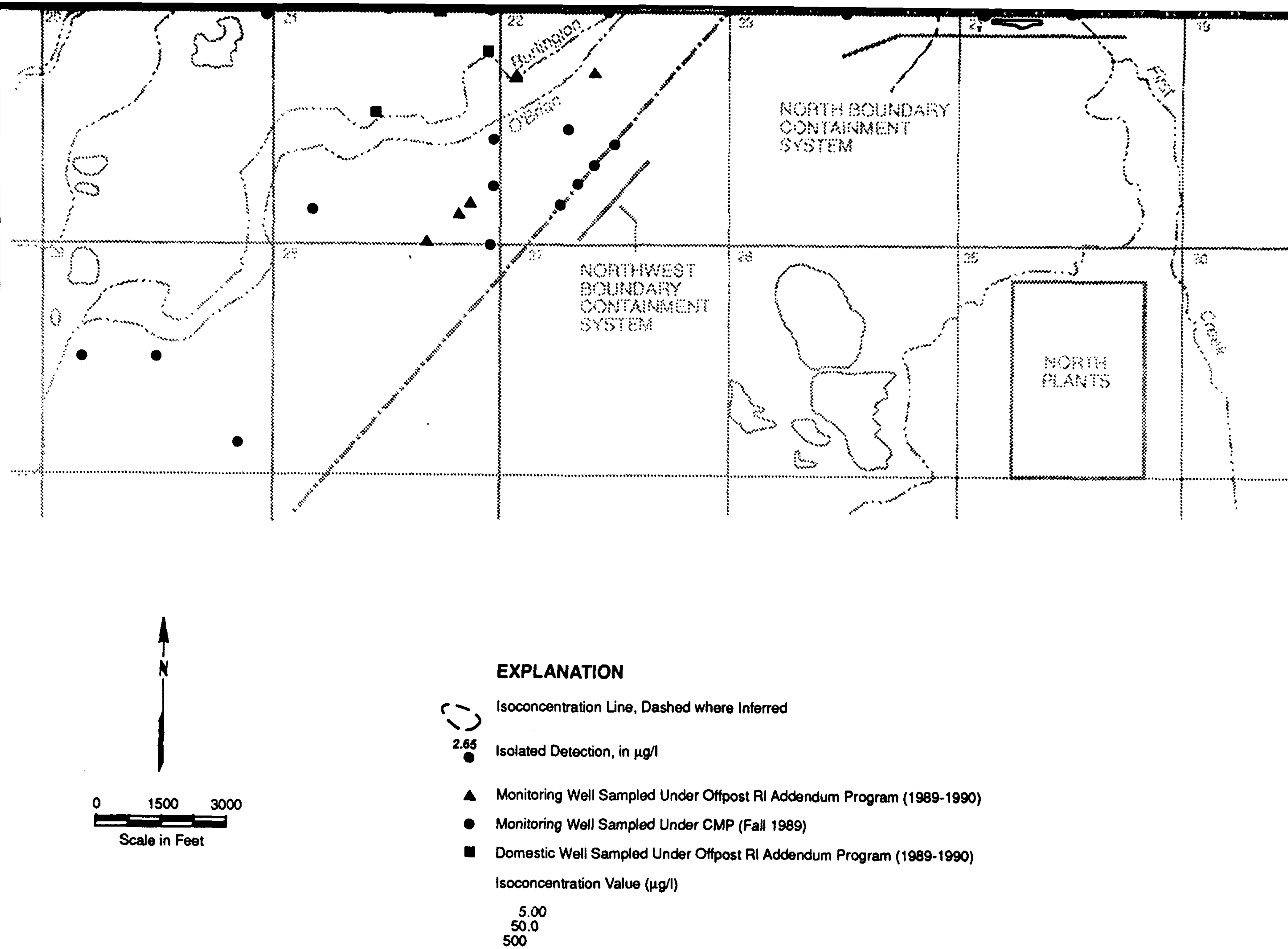
Figure 3

DISTRIBUTION OF DIISOPROPYLMETHYL PHOSPHONATE (DIMP) IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1145



South Platte River
Fulton Ditch
Burlington Canal
Ditch
RMA BOUNDARY
5.00
50.0
500



Prepared for:
Program Manager for
Rocky Mountain Arsenal

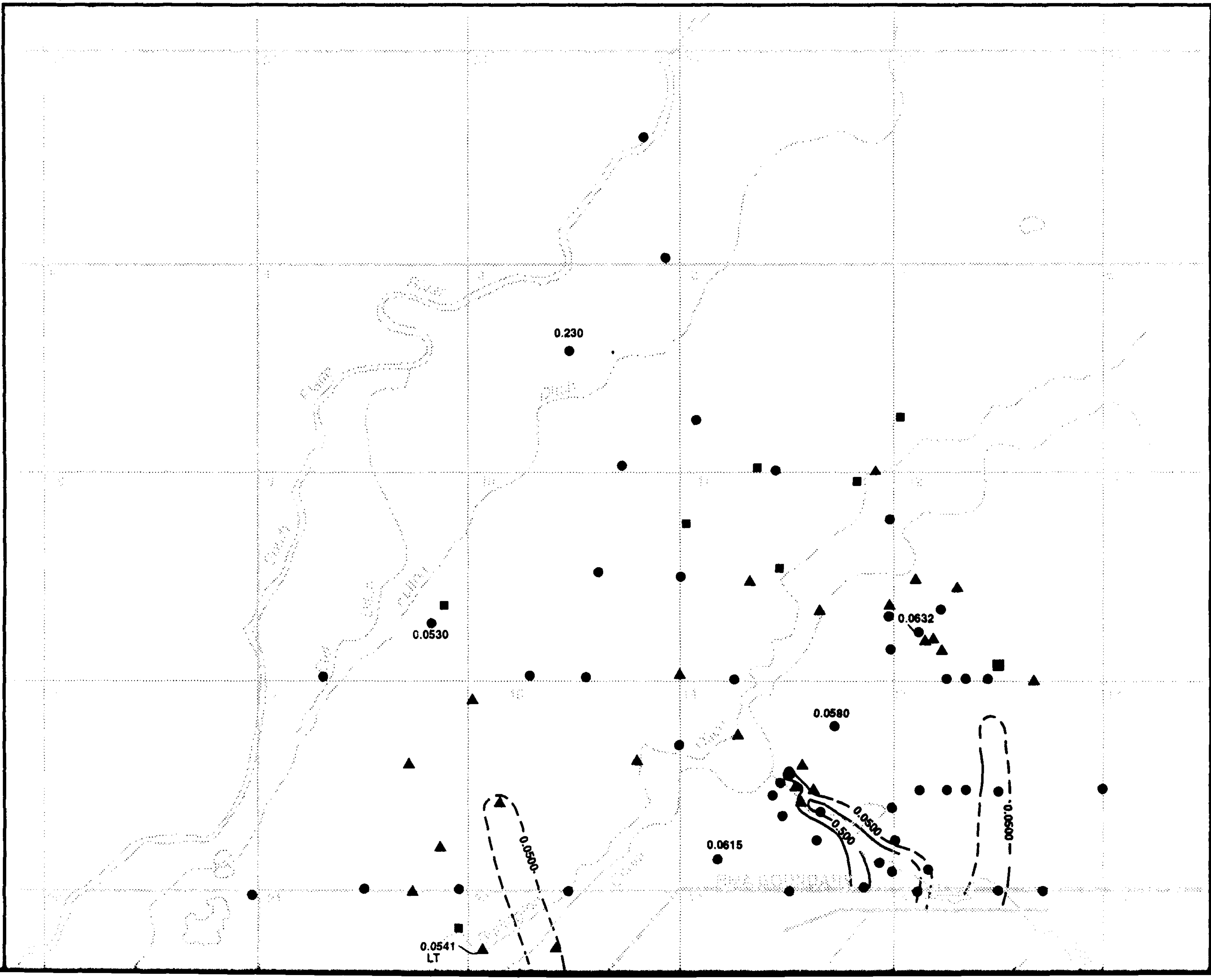
Commerce City, Colorado

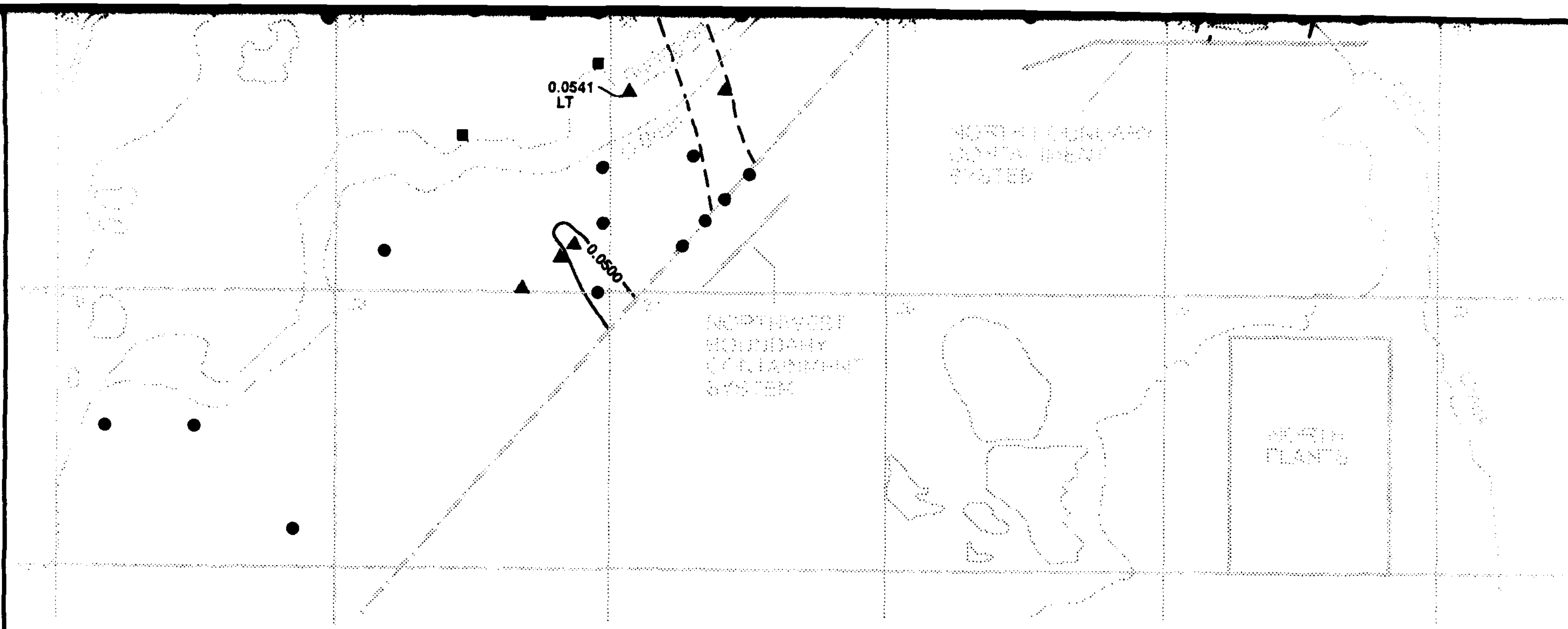
Figure 4

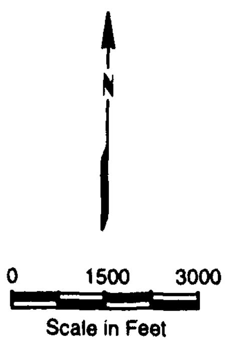
DISTRIBUTION OF DICYCLOPENTADIENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

2

RMA1 1146







EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 ● LT Isolated Detection in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.0500
0.500
5.00

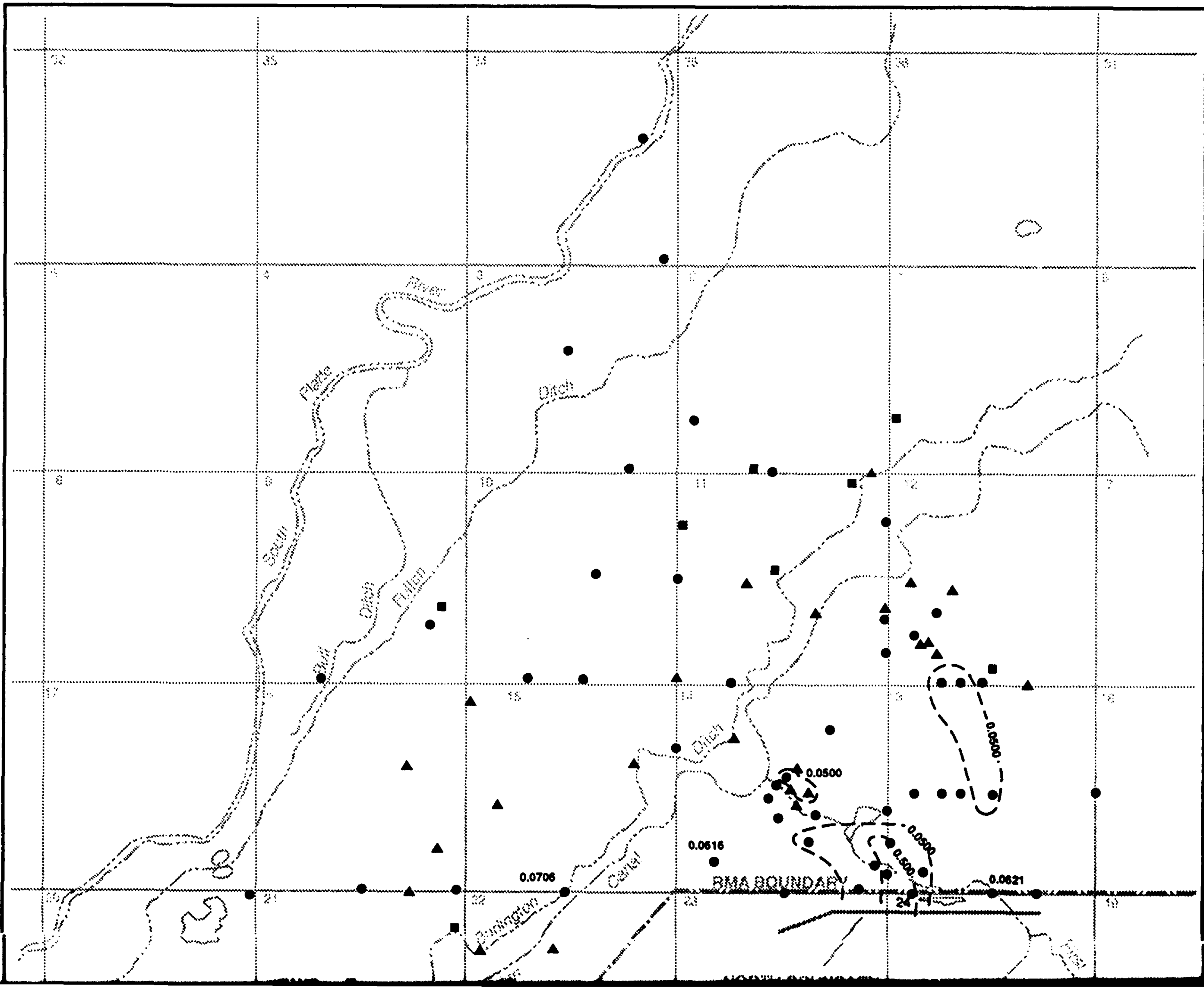
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

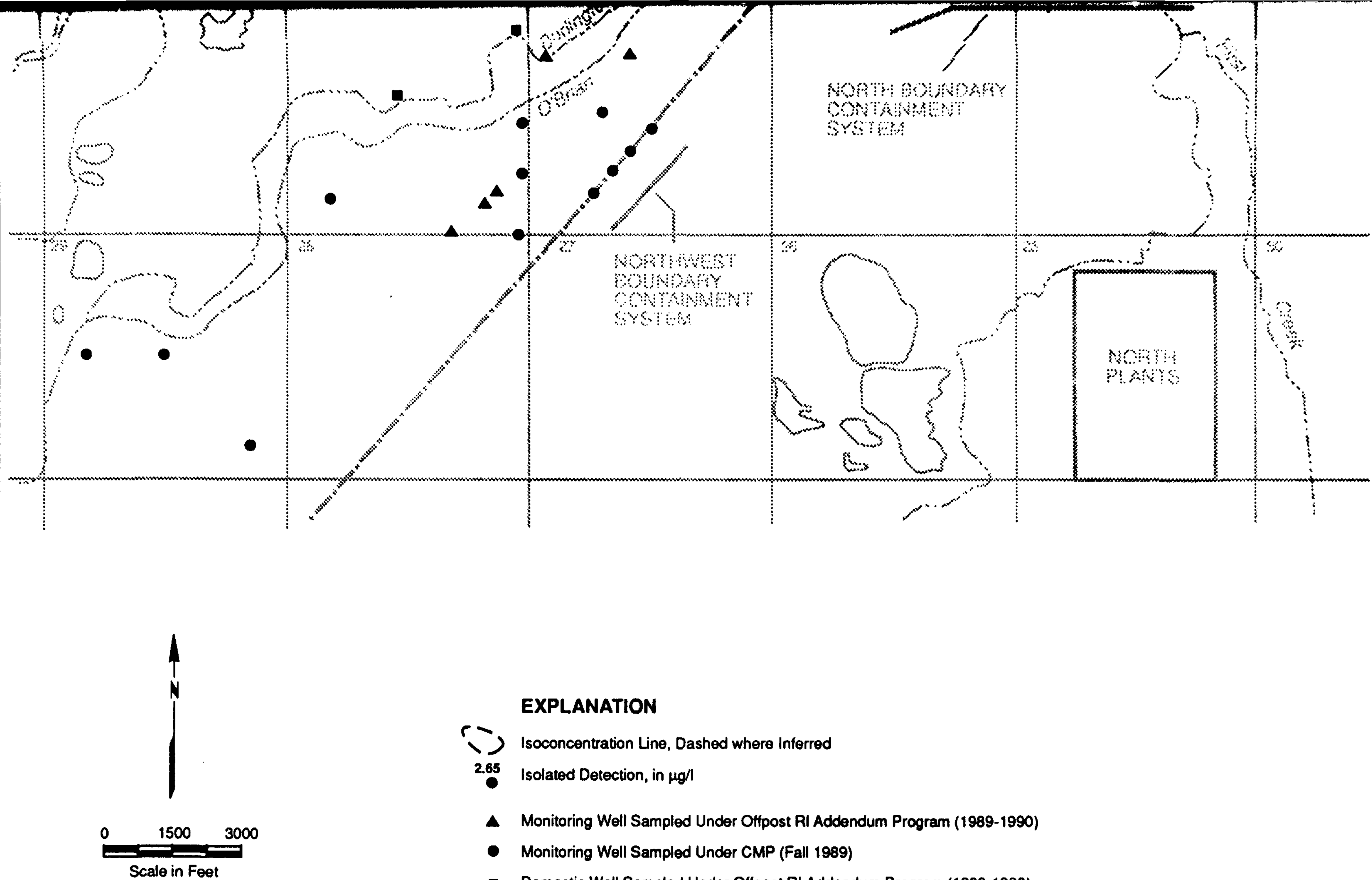
Figure 5

DISTRIBUTION OF DIELDRIN IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1147



South Platte River
Bull Ditch
Fulton Ditch
Ditch
Burlington Canal
RMA BOUNDARY
0.0500
0.500
0.0616
0.0706
0.0621
24



EXPLANATION

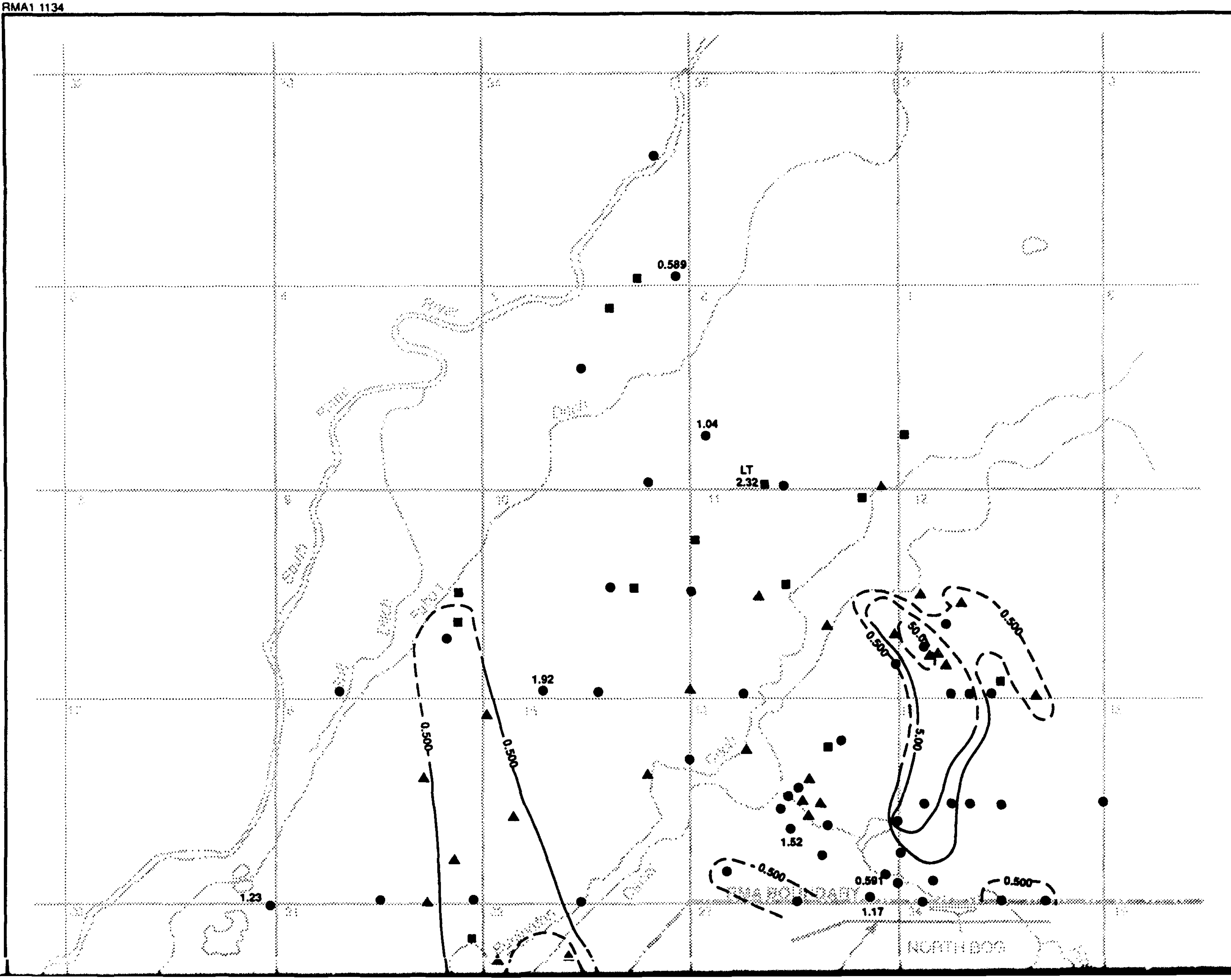
- Isoconcentration Line, Dashed where Inferred
- 2.65 Isolated Detection, in µg/l
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

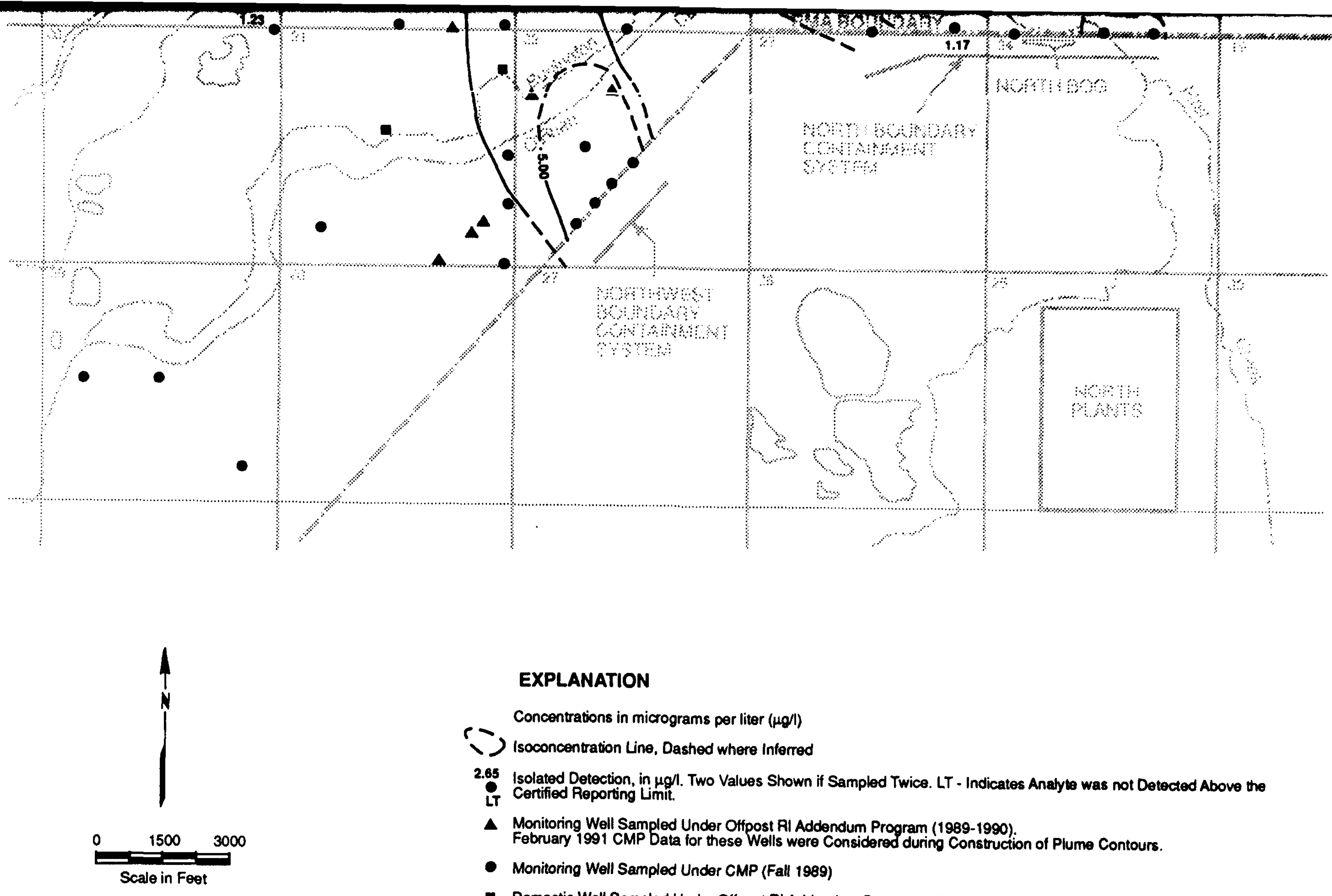
Isoconcentration Value (µg/l)

0.0500
0.500

Prepared for: **Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 6 DISTRIBUTION OF ENDRIN IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1134


0.589
1.04
LT
2.32
1.92
0.500
0.500
50.00
5.00
0.500
0.500
1.52
0.500
0.591
0.500
1.23
1.17
RMA BOUNDARY
NORTH BOG



EXPLANATION

Concentrations in micrograms per liter (µg/l)

Isoconcentration Line, Dashed where Inferred

2.65 LT Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)
0.500
5.00
50.0

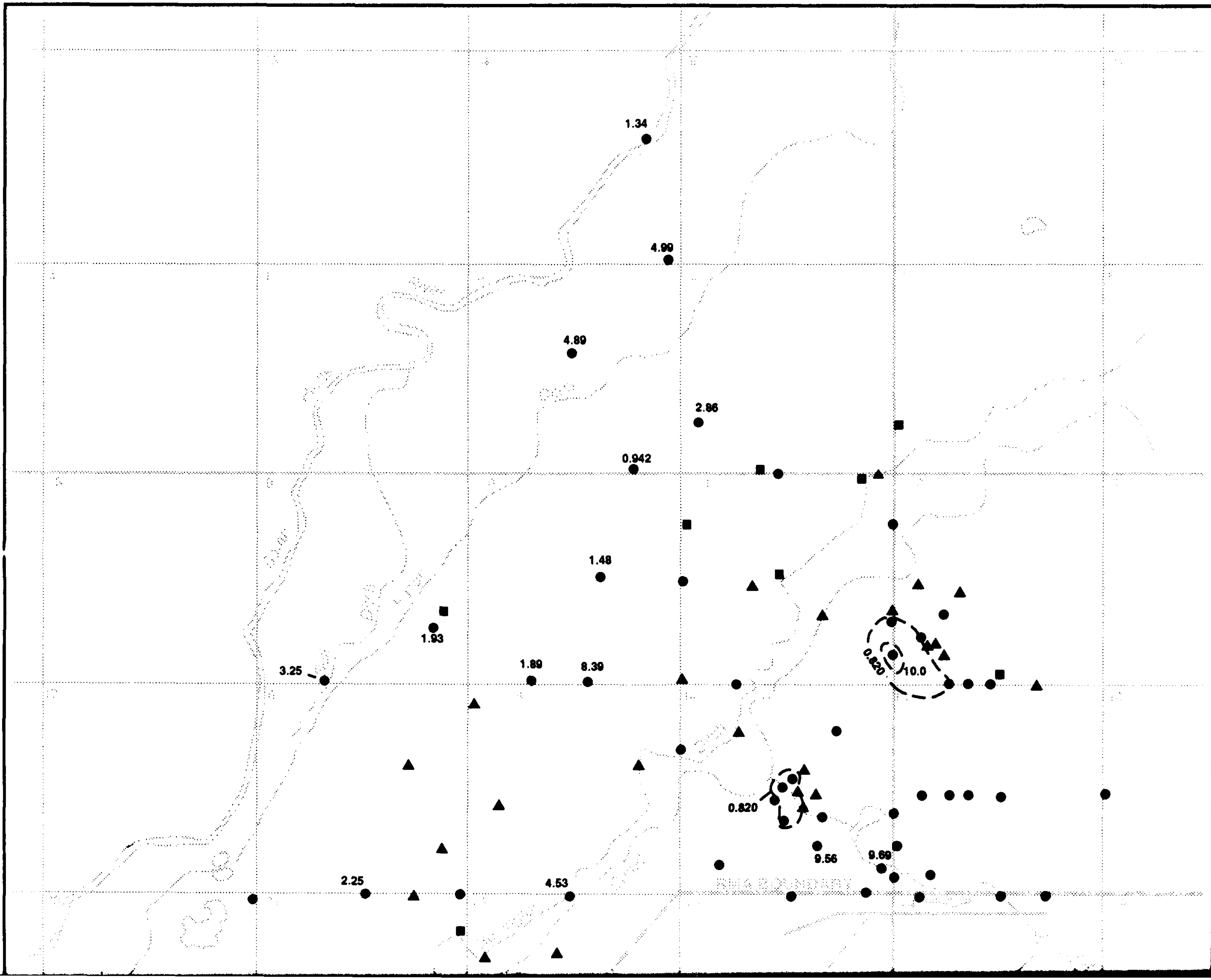
Prepared for:
Program Manager for
Rocky Mountain Arsenal

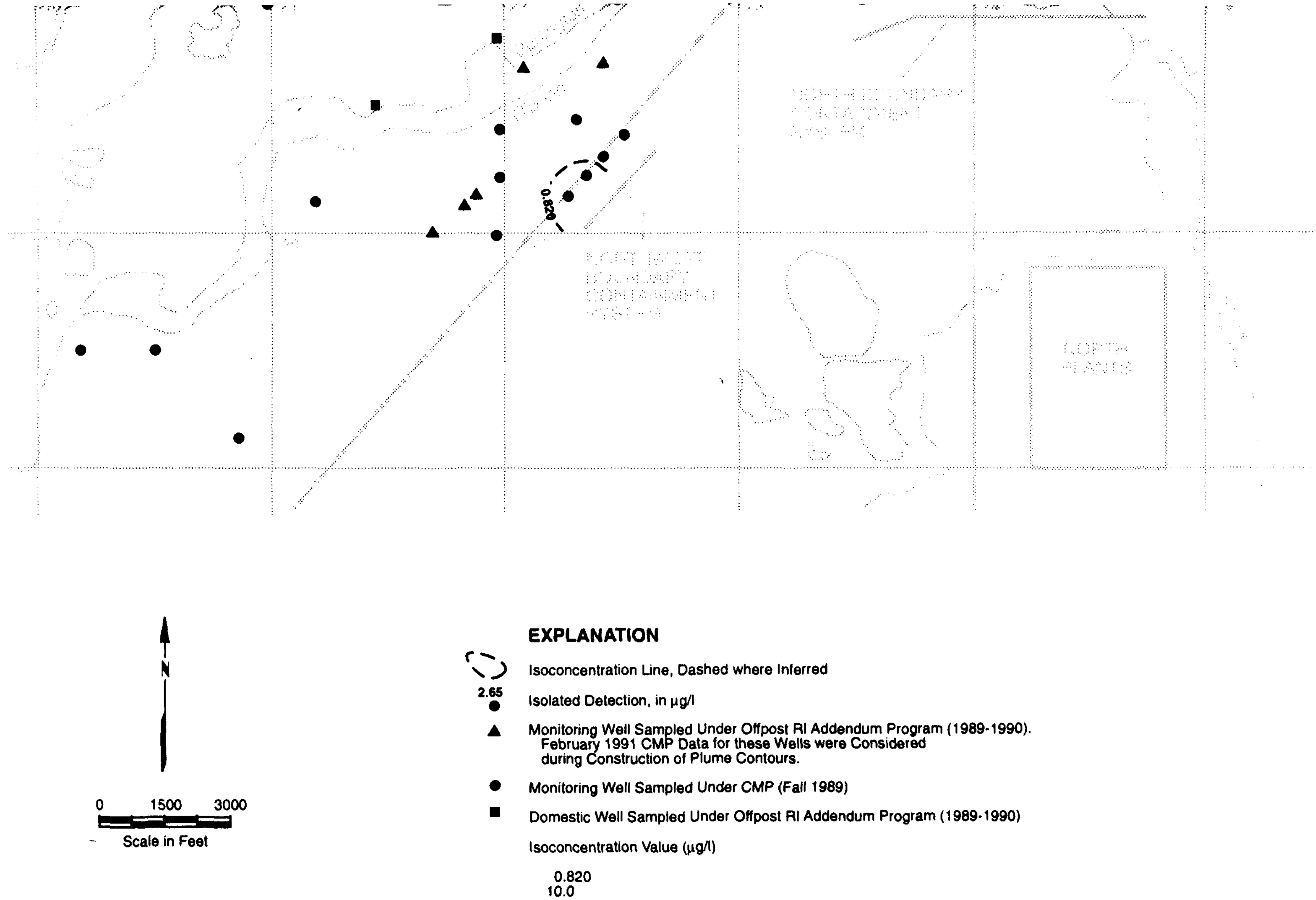
Commerce City, Colorado

Figure 7

DISTRIBUTION OF CHLOROFORM IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1149


1.34
4.99
4.89
2.86
0.942
1.48
1.93
3.25
1.89
8.39
0.820
10.0
0.820
9.56
9.69
2.25
4.53
RMA BOUNDARY



EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 Isolated Detection, in µg/l

Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

Monitoring Well Sampled Under CMP (Fall 1989)

Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.820
10.0

Prepared for:
Program Manager for
Rocky Mountain Arsenal

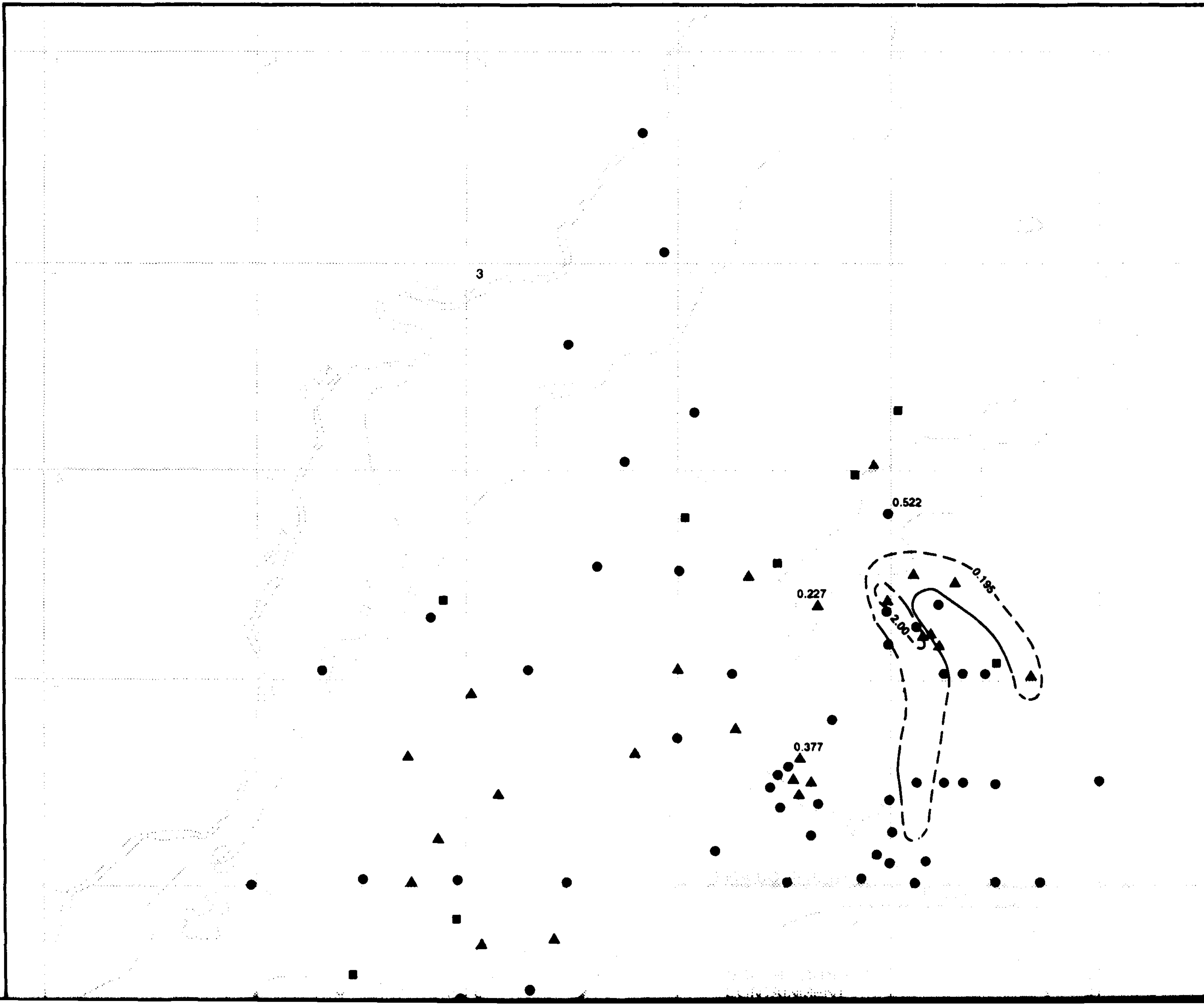
Commerce City, Colorado

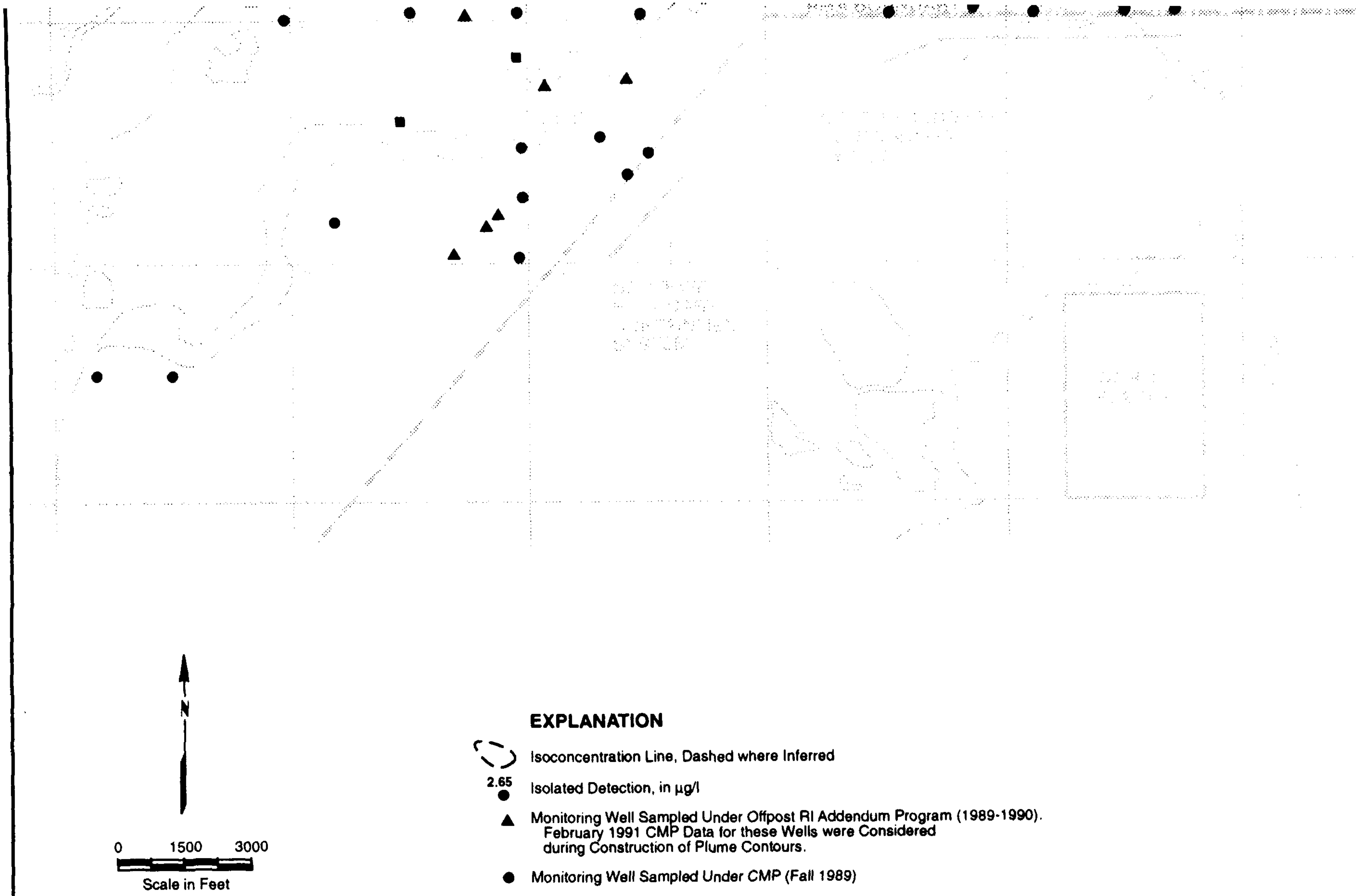
Figure 8

DISTRIBUTION OF CHLOROBENZENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

(2)

RMA1 1150





EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 Isolated Detection, in µg/l
- Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.
- Monitoring Well Sampled Under CMP (Fall 1989)
- Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.195
2.00

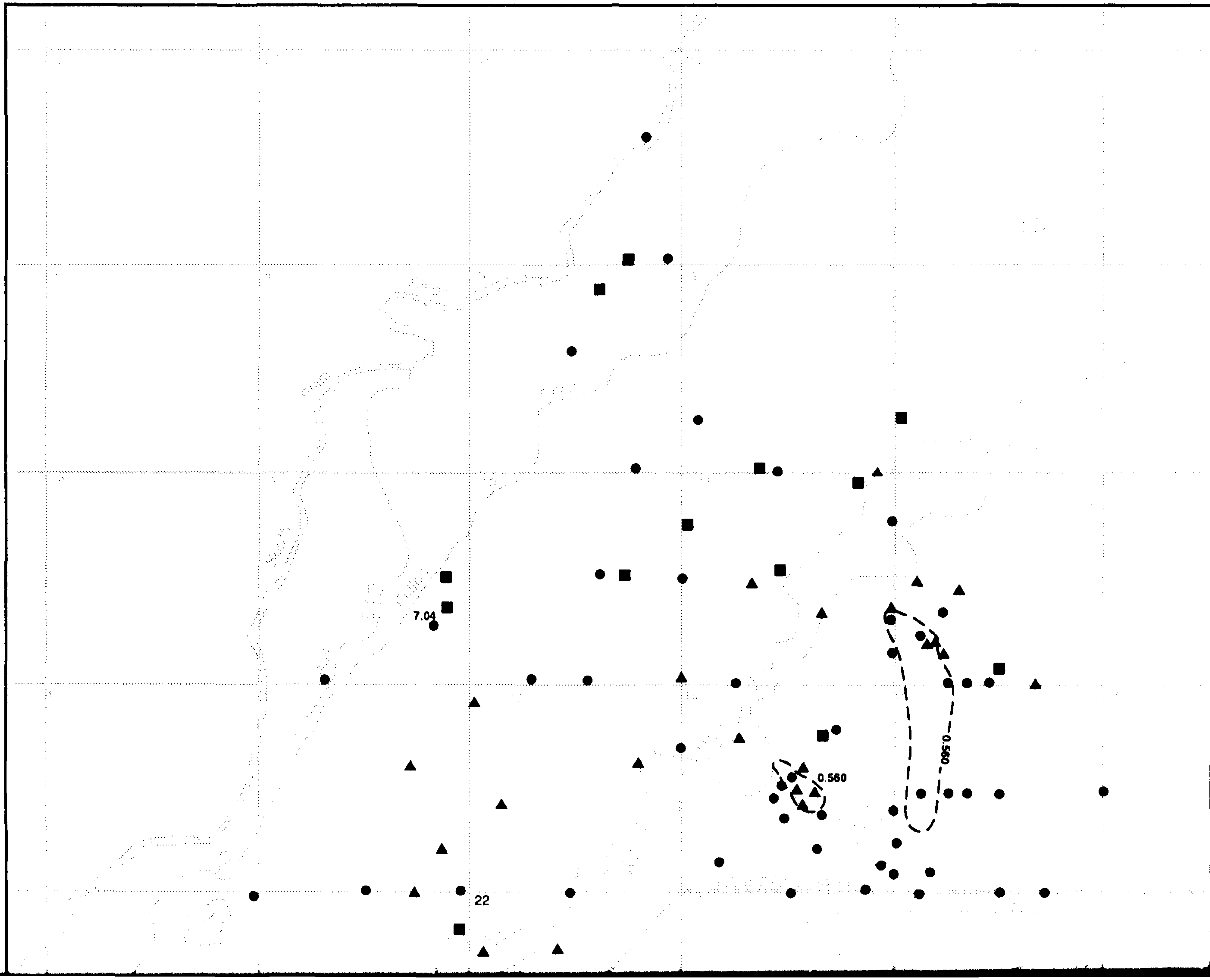
Prepared for:
Program Manager for
Rocky Mountain Arsenal

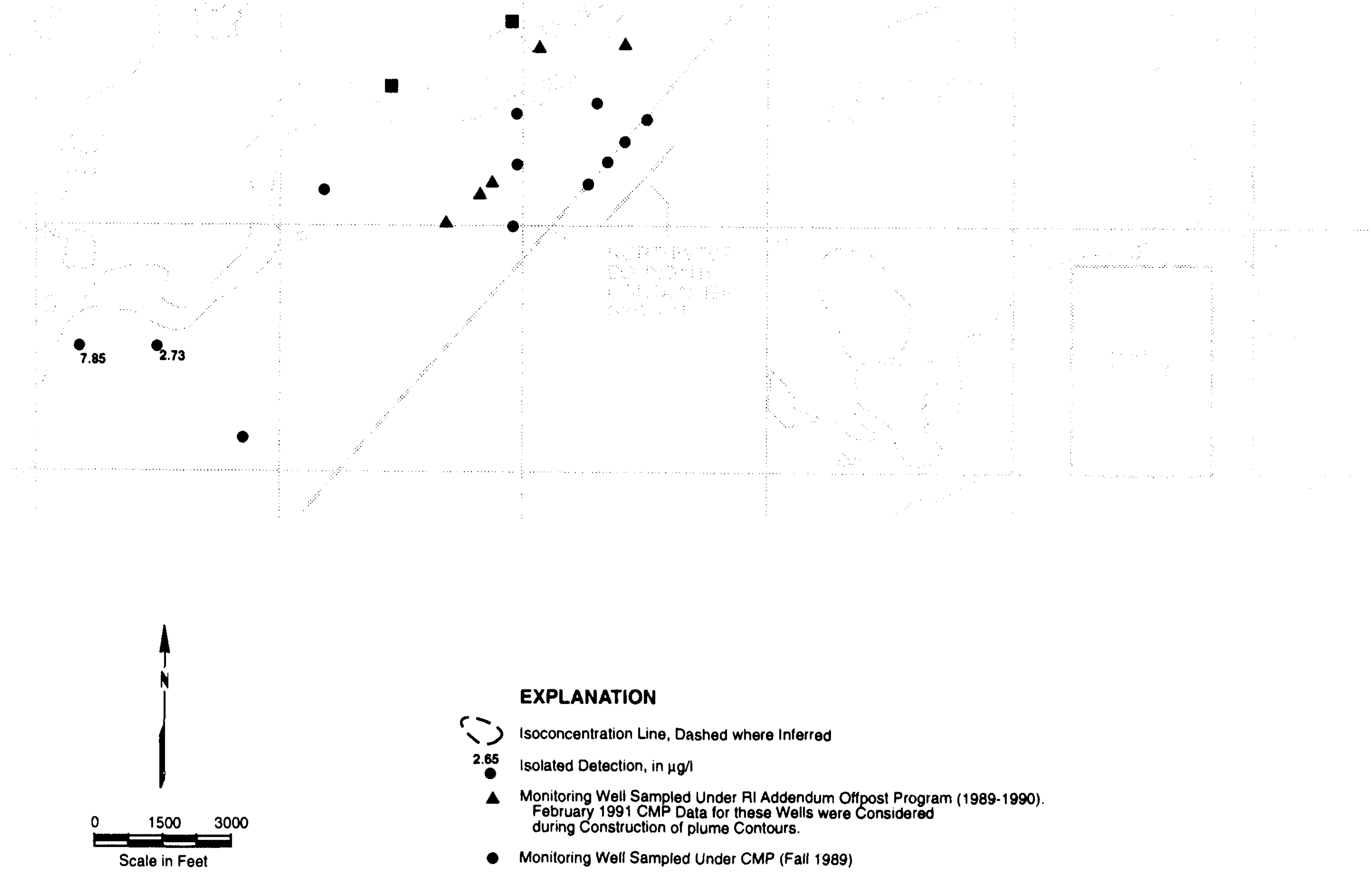
Commerce City, Colorado

Figure 9

DISTRIBUTION OF DIBROMOCHLOROPROPANE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1151





EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 Isolated Detection, in μg/l
- ▲ Monitoring Well Sampled Under RI Addendum Offpost Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of plume Contours.
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (μg/l)

0.560

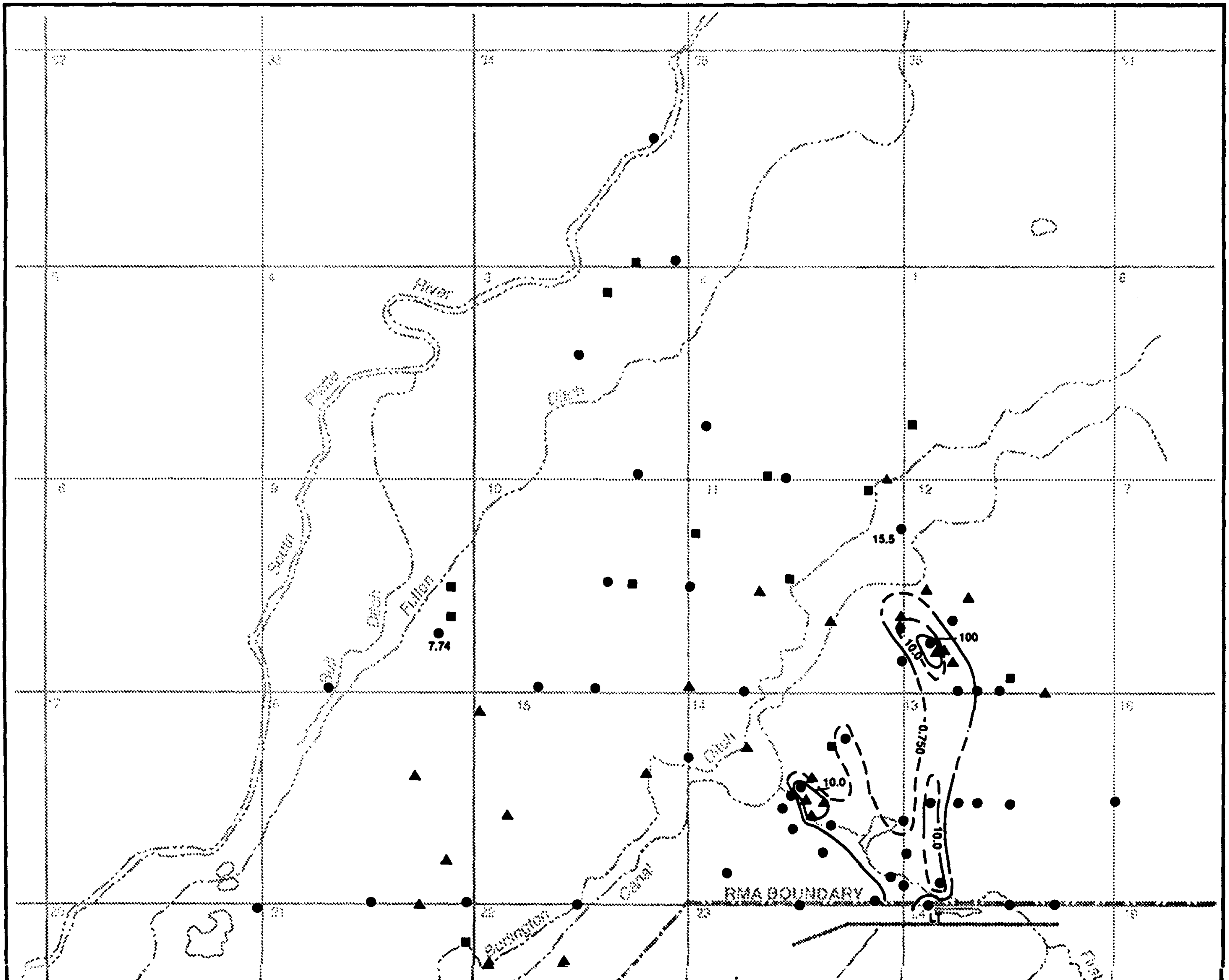
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

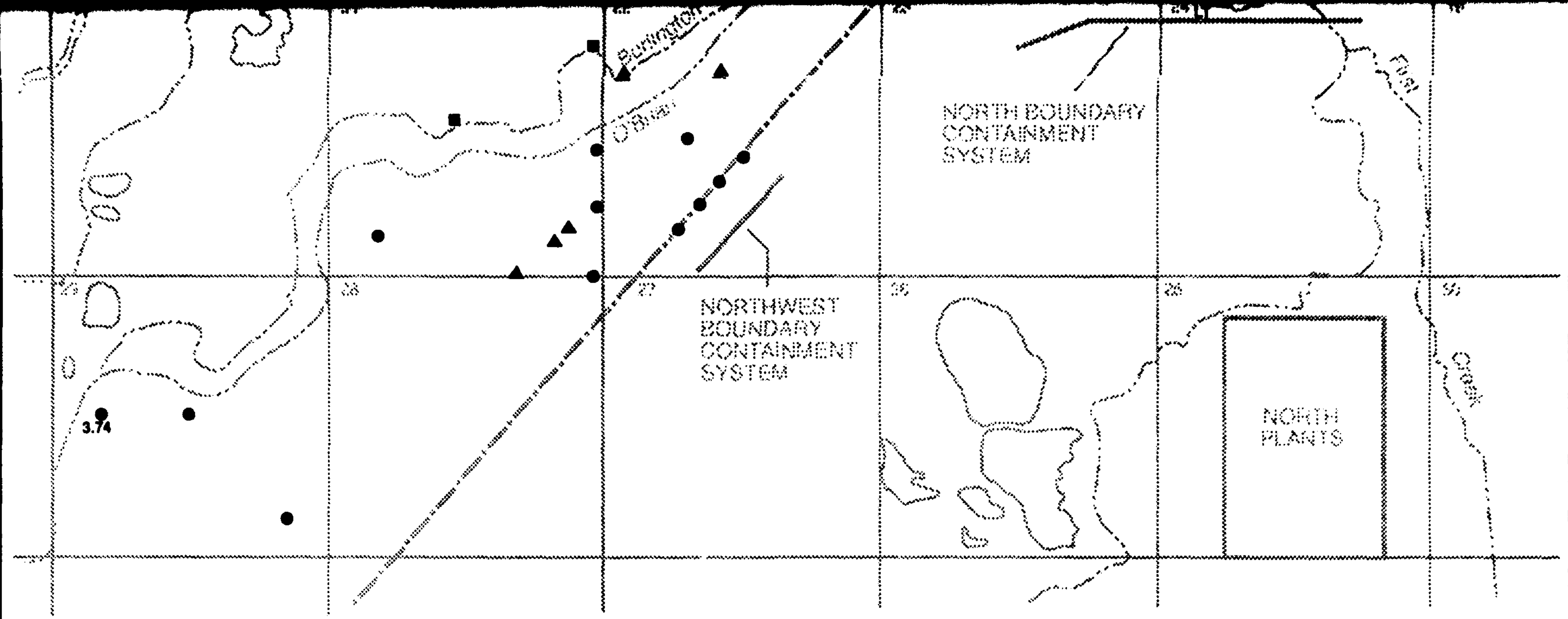
Figure 10

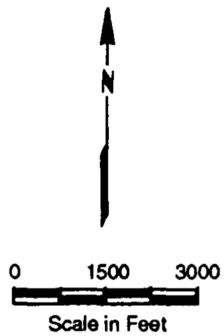
DISTRIBUTION OF TRICHLOROETHENE (TRCLE) IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1152



South
Platte
River
Fulton
Ditch
Burlington
Canal
RMA BOUNDARY
100
10.0
0.750
15.5
7.74





EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 Isolated Detection, in µg/l

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990). February 1991 CMP Data for these Wells were Considered during Construction of Plume Contours.

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

0.750
10.0
100

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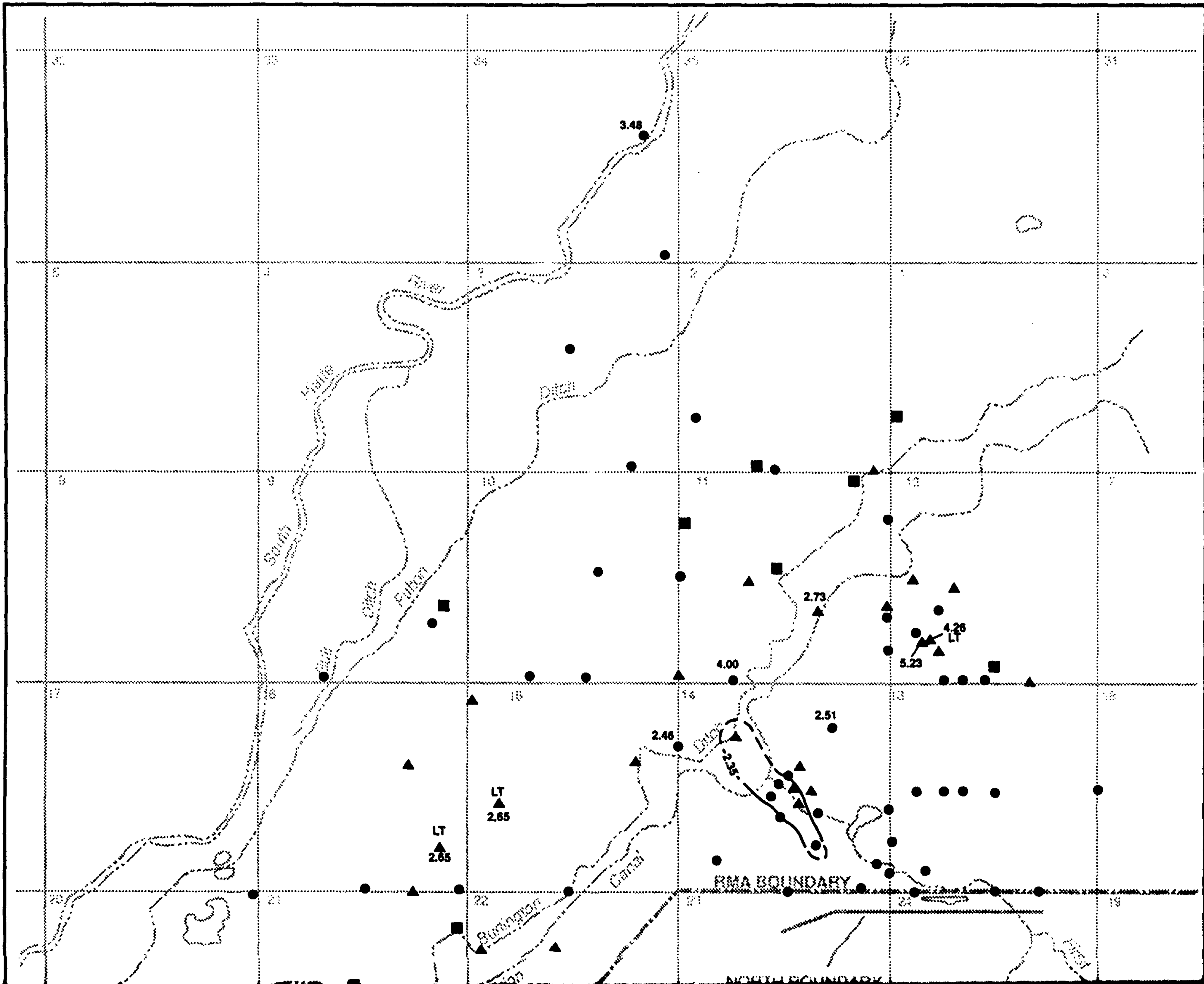
Program Manager for
Rocky Mountain Arsenal

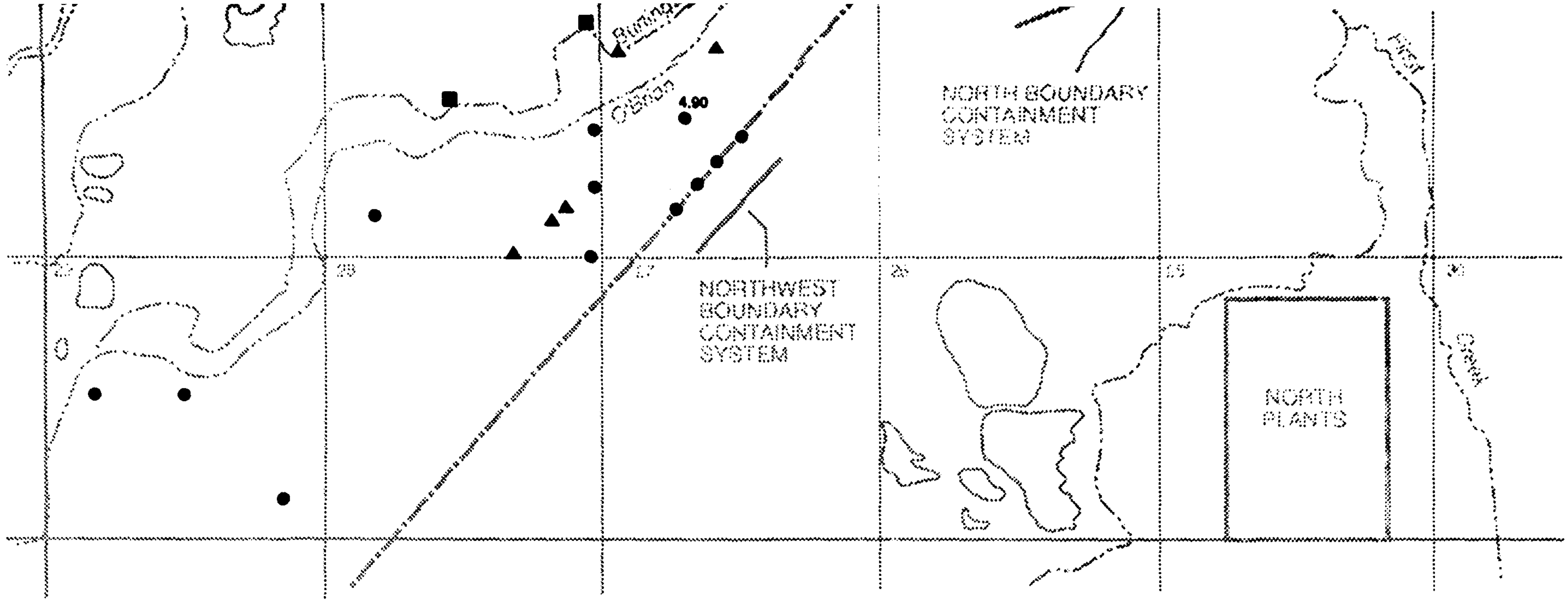
Commerce City, Colorado

Figure 11

DISTRIBUTION OF TETRACHLOROETHENE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1153


3.48
South
Platte
River
Fulton
Ditch
Ditch
Burlington
Canal
Ditch
2.73
4.26
LT
5.23
4.00
2.51
2.46
2.35
LT
2.65
LT
2.65
RMA BOUNDARY
NORTH BOUNDARY
First
17
15
14
13
18
22
21
24
19
10
11
12
7



N

0 1500 3000
Scale in Feet

EXPLANATION

Isoconcentration Line, Dashed where Inferred

2.65 LT — Isolated Detection, in µg/l. Two Values Shown if Sampled Twice. LT - Indicates Analyte was not Detected Above the Certified Reporting Limit.

▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)

● Monitoring Well Sampled Under CMP (Fall 1989)

■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

2.35

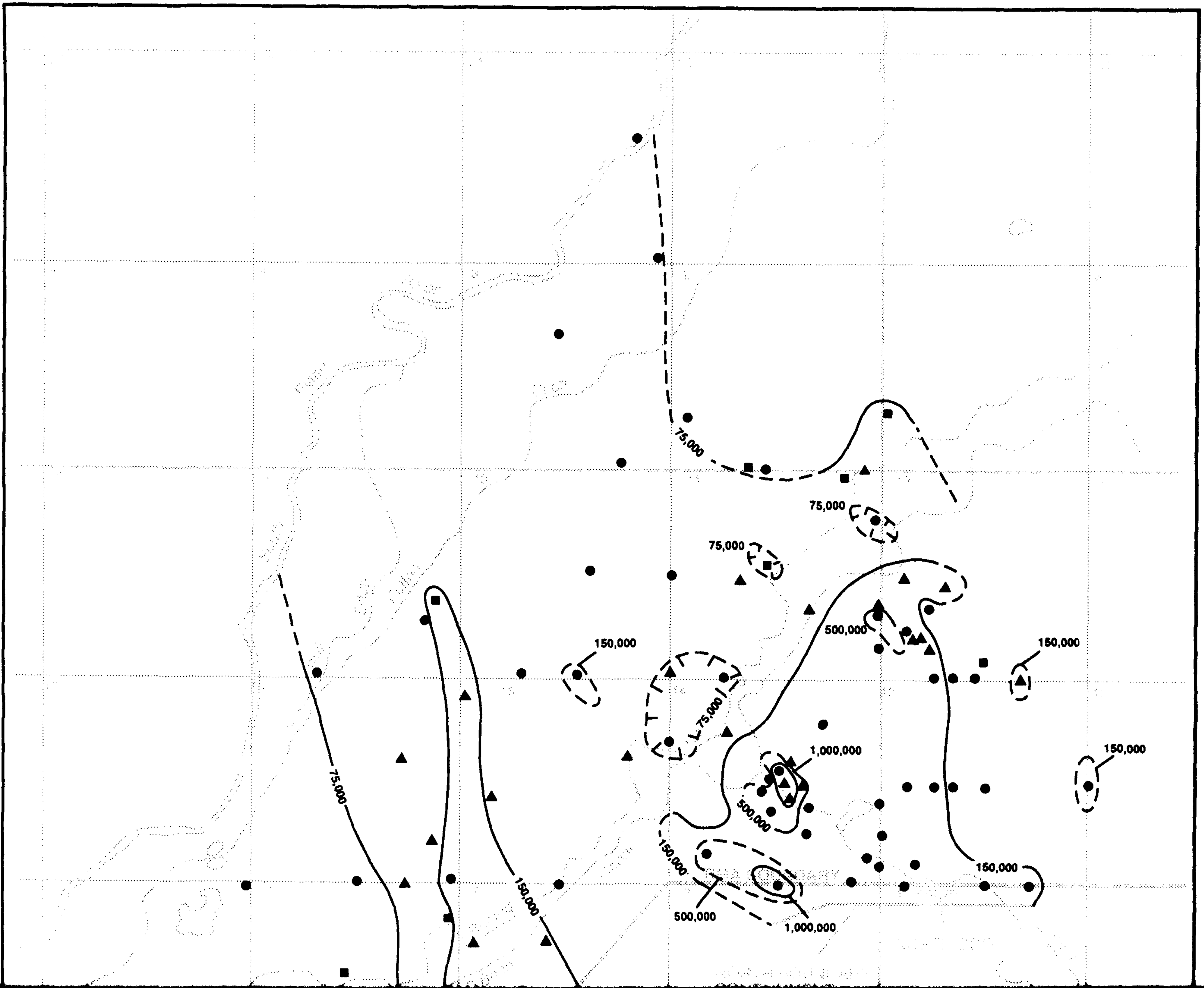
Prepared for:
Program Manager for
Rocky Mountain Arsenal

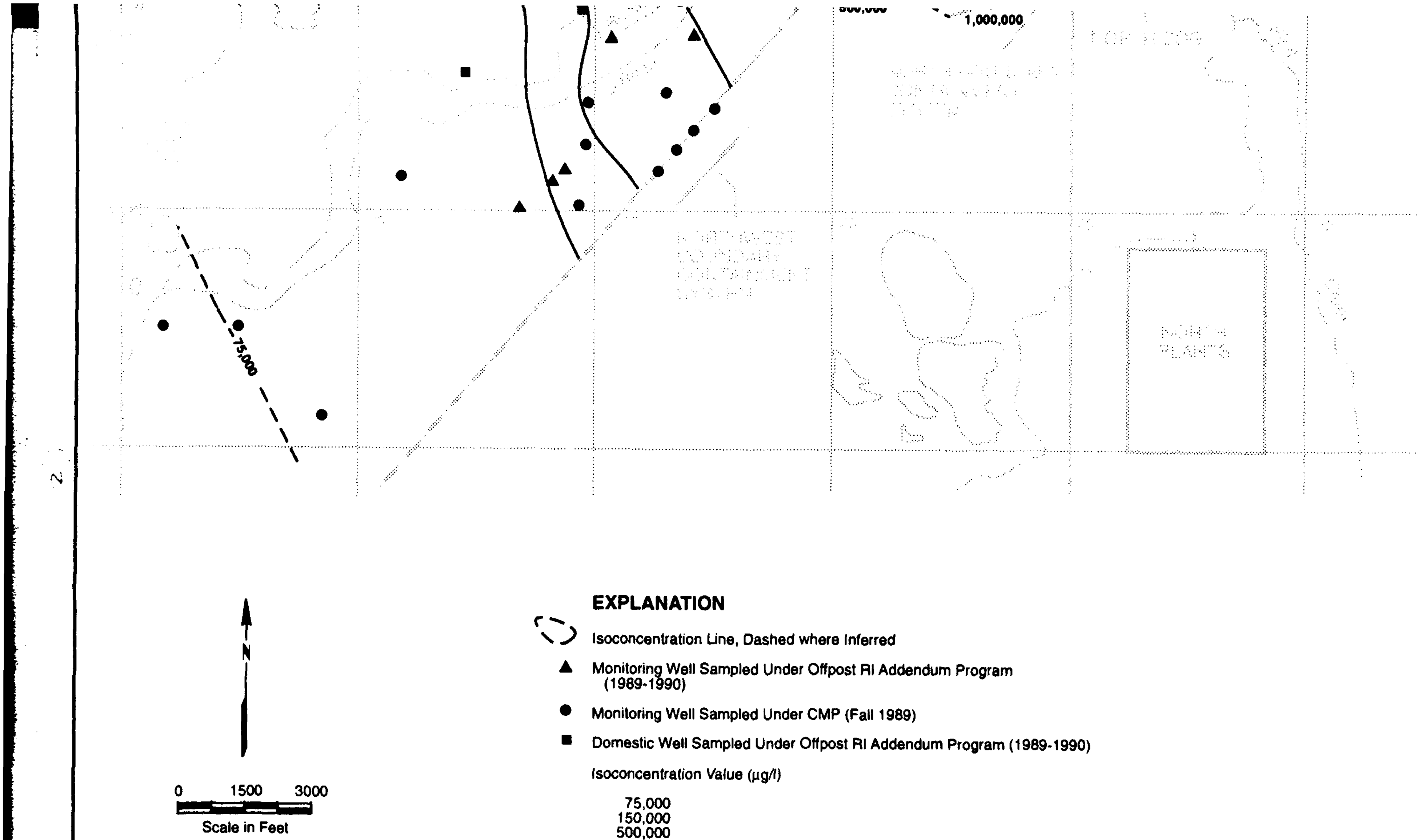
Commerce City, Colorado

Figure 12

DISTRIBUTION OF ARSENIC IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1140


75,000
75,000
75,000
150,000
L 75,000
500,000
150,000
150,000
1,000,000
500,000
150,000
150,000
500,000
1,000,000
75,000
150,000



EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under Offpost RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

75,000
150,000
500,000
1,000,000

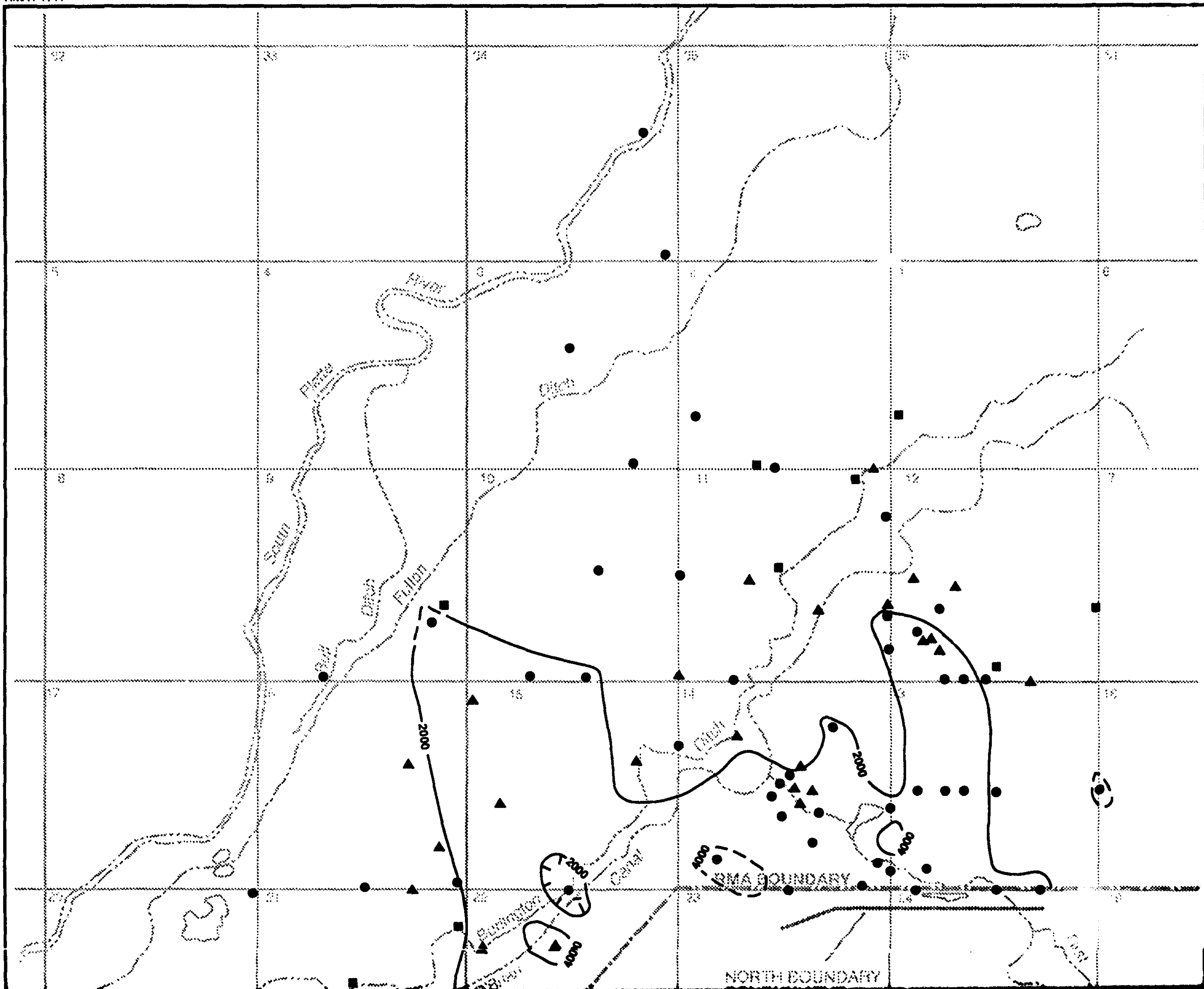
Prepared for:
Program Manager for Rocky Mountain Arsenal

Commerce City, Colorado

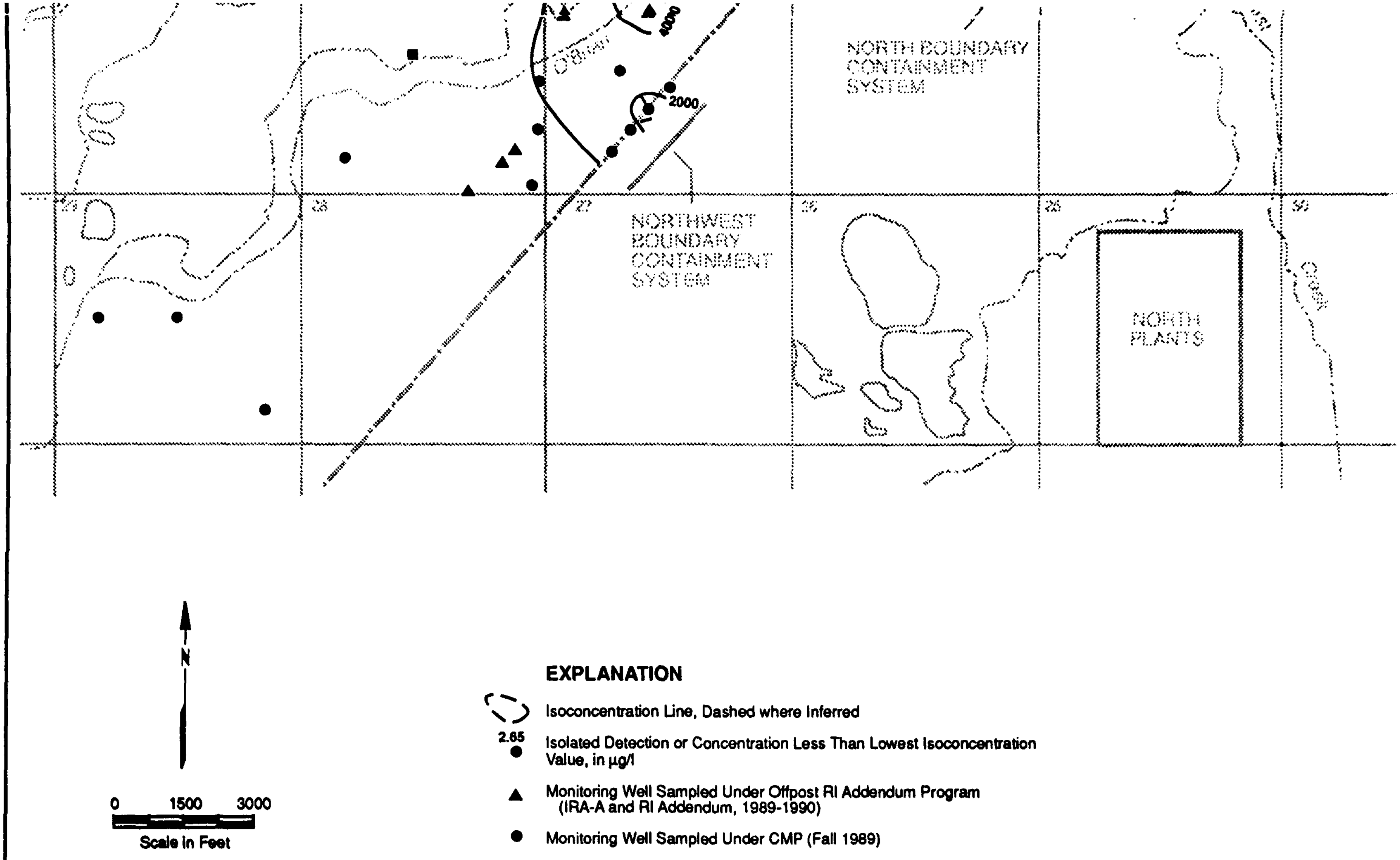
Figure 13

DISTRIBUTION OF CHLORIDE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1141



South Platte River
Fulton Ditch
Ditch
Burlington Canal
RMA BOUNDARY
NORTH BOUNDARY
2000
4000



EXPLANATION

- Isoconcentration Line, Dashed where Inferred
- 2.65 ● Isolated Detection or Concentration Less Than Lowest Isoconcentration Value, in µg/l
- ▲ Monitoring Well Sampled Under Offpost RI Addendum Program (IRA-A and RI Addendum, 1989-1990)
- ● Monitoring Well Sampled Under CMP (Fall 1989)
- ■ Domestic Well Sampled Under RI Addendum Program (1989-1990)

Isoconcentration Value (µg/l)

2000
4000

Prepared for:
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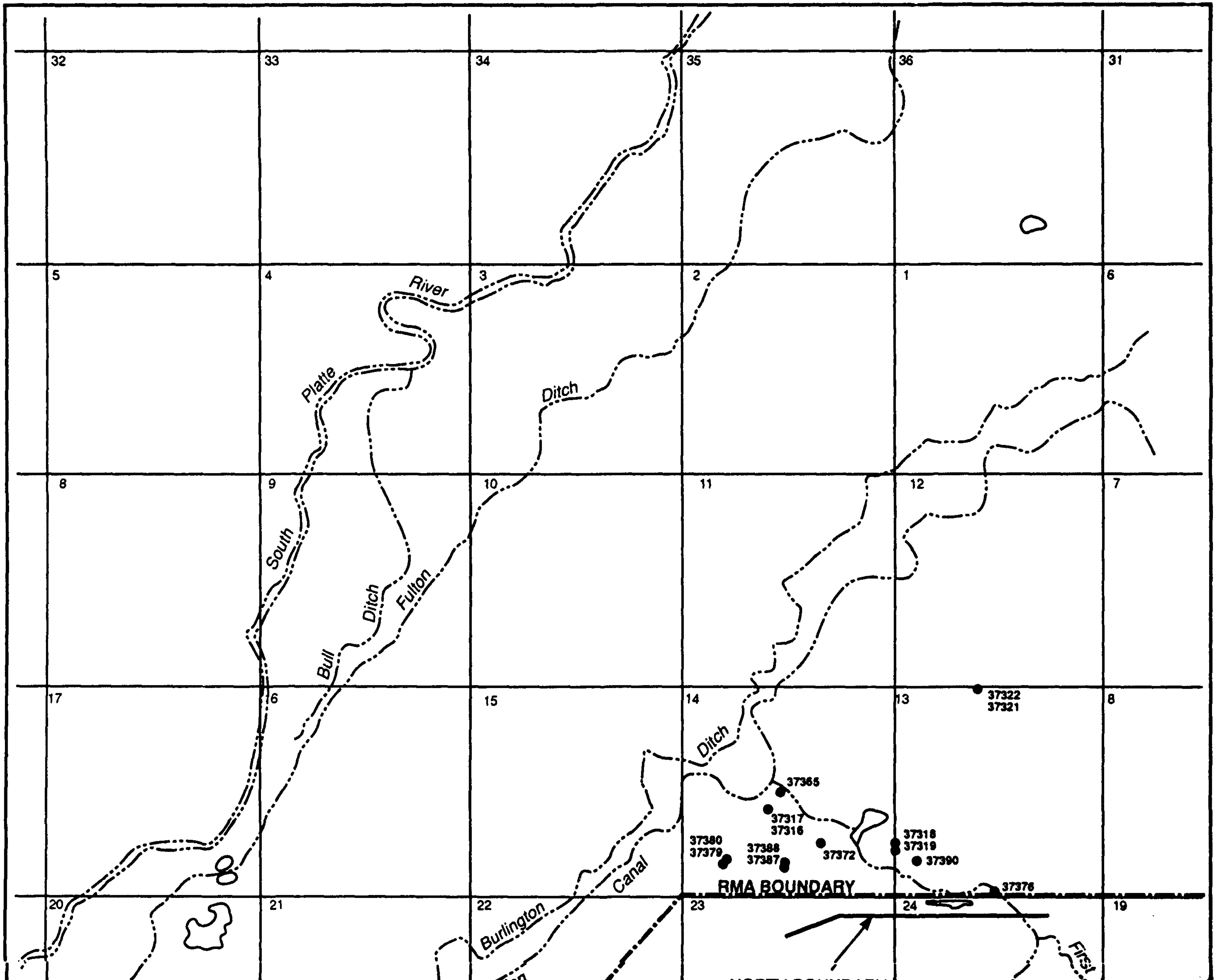
Rocky Mountain Arsenal

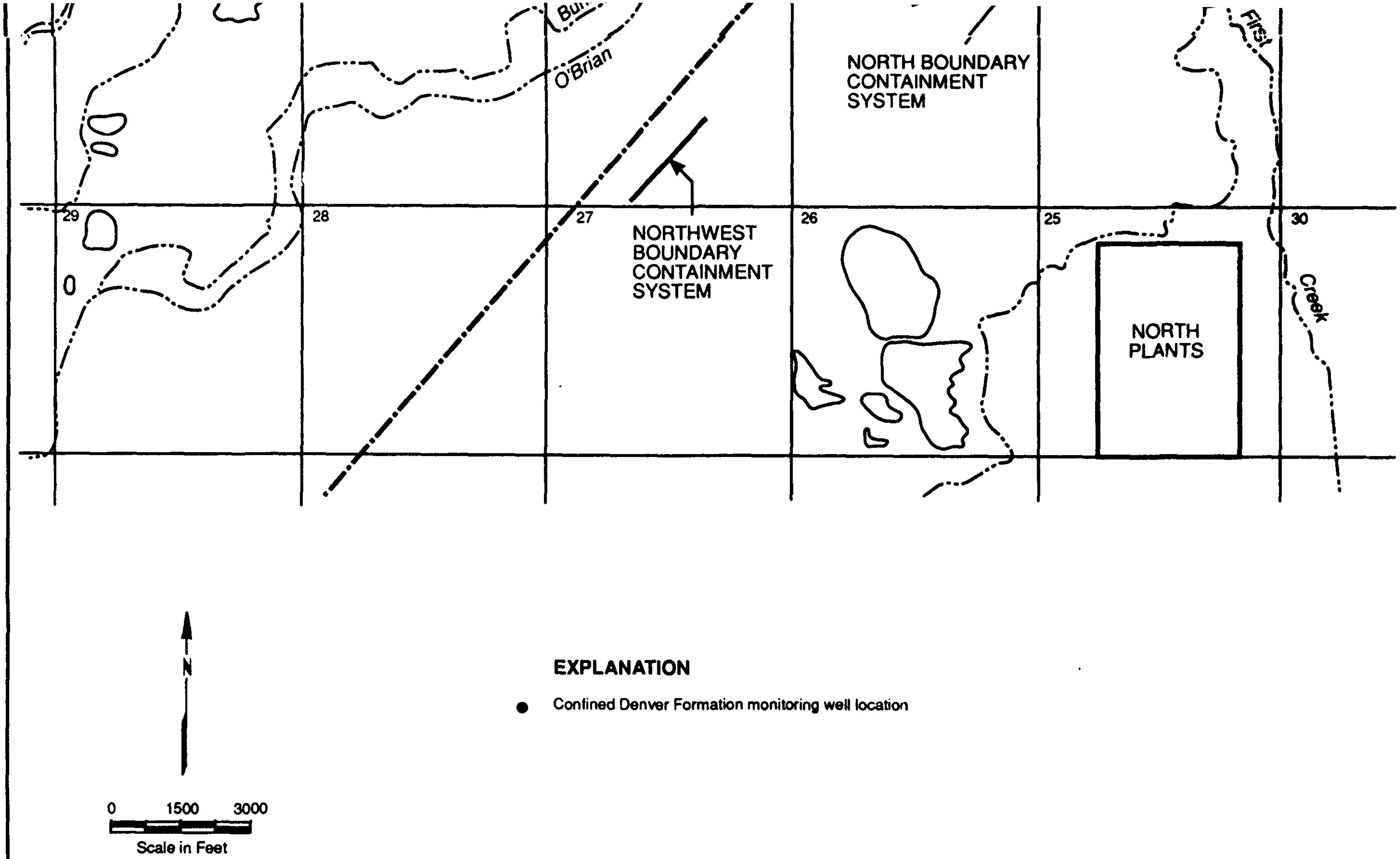
Commerce City, Colorado

Figure 14

DISTRIBUTION OF FLUORIDE IN THE OFFPOST UNCONFINED FLOW SYSTEM

RMA1 1139


32
33
34
35
36
31
5
4
3
2
1
6
8
9
10
11
12
7
17
16
15
14
13
8
20
21
22
23
24
19
River
Platte
South
Ditch
Bull
Ditch
Fulton
Ditch
Ditch
Canal
Burlington
First
RMA BOUNDARY
37322
37321
37365
37317
37316
37318
37319
37380
37379
37388
37387
37372
37390
37376



EXPLANATION

● Confined Denver Formation monitoring well location

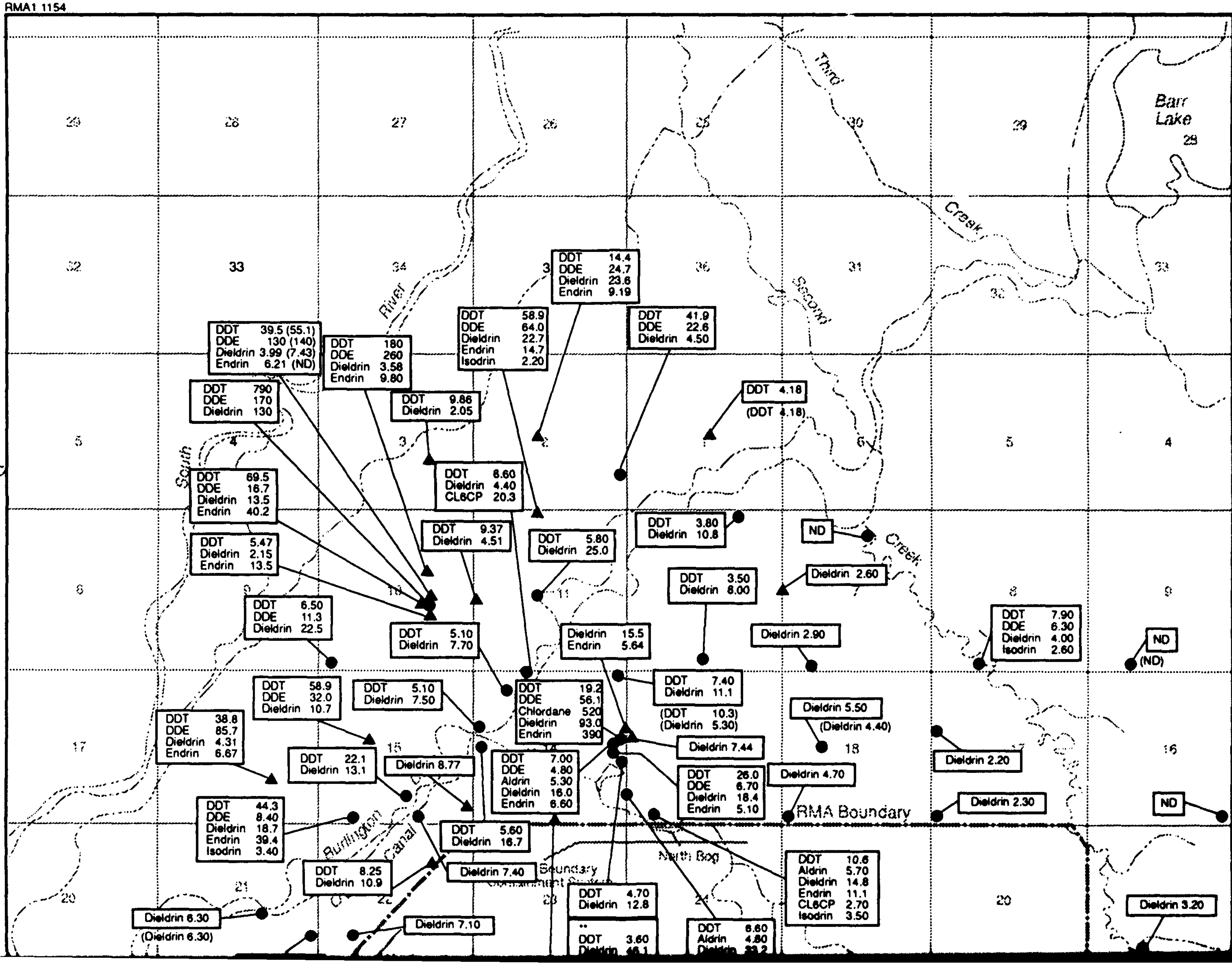
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

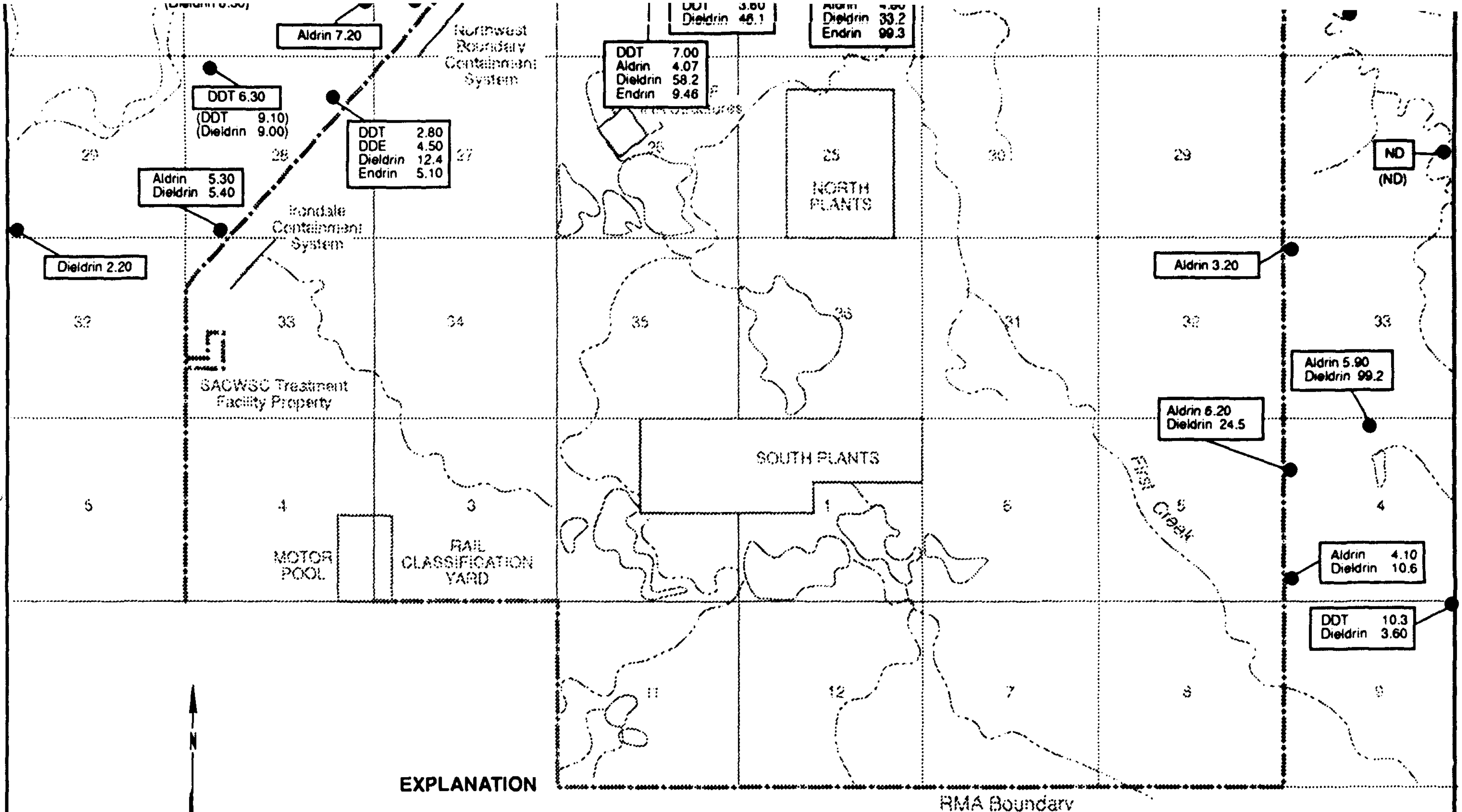
Figure 15

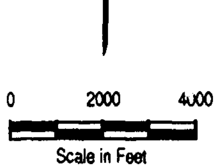
OFFPOST OPERABLE UNIT CONFINED DENVER FORMATION MONITORING WELL NETWORK

RMA1 1154



Barr Lake
Third Creek
Second Creek
South River
Burlington Canal
RMA Boundary
North Bog
Boundary Containment System
DDT 14.4
DDE 24.7
Dieldrin 23.6
Endrin 9.19
DDT 58.9
DDE 64.0
Dieldrin 22.7
Endrin 14.7
Isodrin 2.20
DDT 41.9
DDE 22.6
Dieldrin 4.50
DDT 39.5 (55.1)
DDE 130 (140)
Dieldrin 3.99 (7.43)
Endrin 6.21 (ND)
DDT 180
DDE 260
Dieldrin 3.58
Endrin 9.80
DDT 790
DDE 170
Dieldrin 130
DDT 9.86
Dieldrin 2.05
DDT 4.18
(DDT 4.18)
DDT 69.5
DDE 16.7
Dieldrin 13.5
Endrin 40.2
DDT 8.60
Dieldrin 4.40
CL6CP 20.3
DDT 9.37
Dieldrin 4.51
DDT 5.47
Dieldrin 2.15
Endrin 13.5
DDT 5.80
Dieldrin 25.0
DDT 3.80
Dieldrin 10.8
ND
Dieldrin 2.60
DDT 3.50
Dieldrin 8.00
DDT 6.50
DDE 11.3
Dieldrin 22.5
DDT 5.10
Dieldrin 7.70
Dieldrin 15.5
Endrin 5.64
Dieldrin 2.90
DDT 7.90
DDE 6.30
Dieldrin 4.00
Isodrin 2.60
ND
(ND)
DDT 58.9
DDE 32.0
Dieldrin 10.7
DDT 5.10
Dieldrin 7.50
DDT 19.2
DDE 56.1
Chlordane 520
Dieldrin 93.0
Endrin 390
DDT 7.40
Dieldrin 11.1
(DDT 10.3)
(Dieldrin 5.30)
Dieldrin 5.50
(Dieldrin 4.40)
DDT 38.8
DDE 85.7
Dieldrin 4.31
Endrin 6.67
DDT 22.1
Dieldrin 13.1
Dieldrin 8.77
DDT 7.00
DDE 4.80
Aldrin 5.30
Dieldrin 16.0
Endrin 6.60
Dieldrin 7.44
DDT 26.0
DDE 6.70
Dieldrin 18.4
Endrin 5.10
Dieldrin 4.70
Dieldrin 2.20
Dieldrin 2.30
ND
DDT 44.3
DDE 8.40
Dieldrin 18.7
Endrin 39.4
Isodrin 3.40
DDT 5.60
Dieldrin 16.7
DDT 8.25
Dieldrin 10.9
Dieldrin 7.40
DDT 4.70
Dieldrin 12.8
DDT 10.6
Aldrin 5.70
Dieldrin 14.8
Endrin 11.1
CL6CP 2.70
Isodrin 3.50
Dieldrin 3.20
Dieldrin 6.30
(Dieldrin 6.30)
Dieldrin 7.10
DDT 3.60
DDT 6.60
Aldrin 4.80





EXPLANATION

- ● Surficial Soil Sampling Location, June-July 1990
- ▲ Surficial Soil Samping Location, May 1991
- ( ) Duplicate Sample Results

Concentrations in micrograms per kilogram

CL6CP	Hexachlorocyclopentadiene
DDT	2,2 - Bis (parachlorophenyl) - 1,1,1 - Trichloroethane
DDE	2,2 - Bis (parachlorophenyl) - 1,1 - Dichlorethane
ND	Not Detected at or above the Certified Reporting Limit

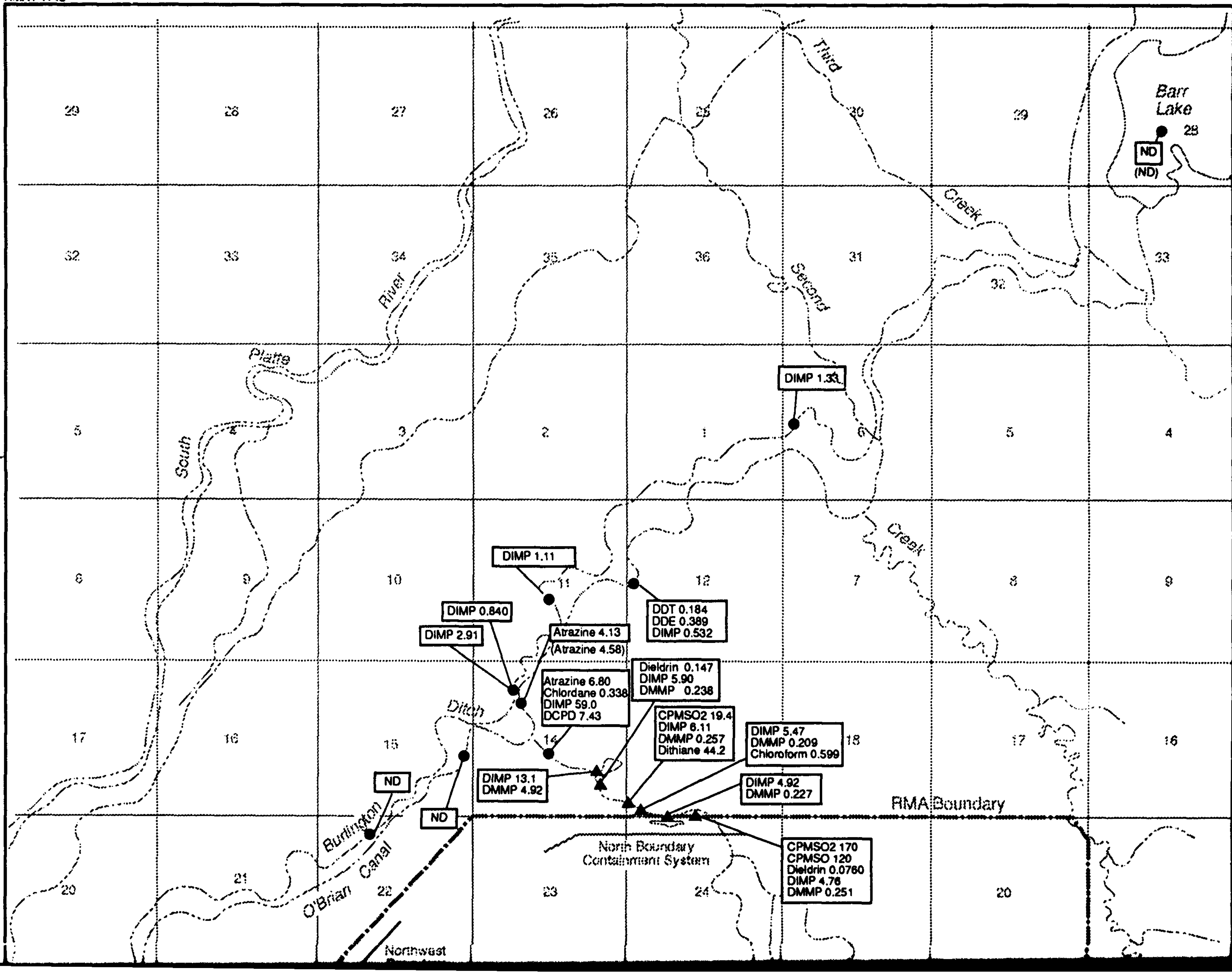
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

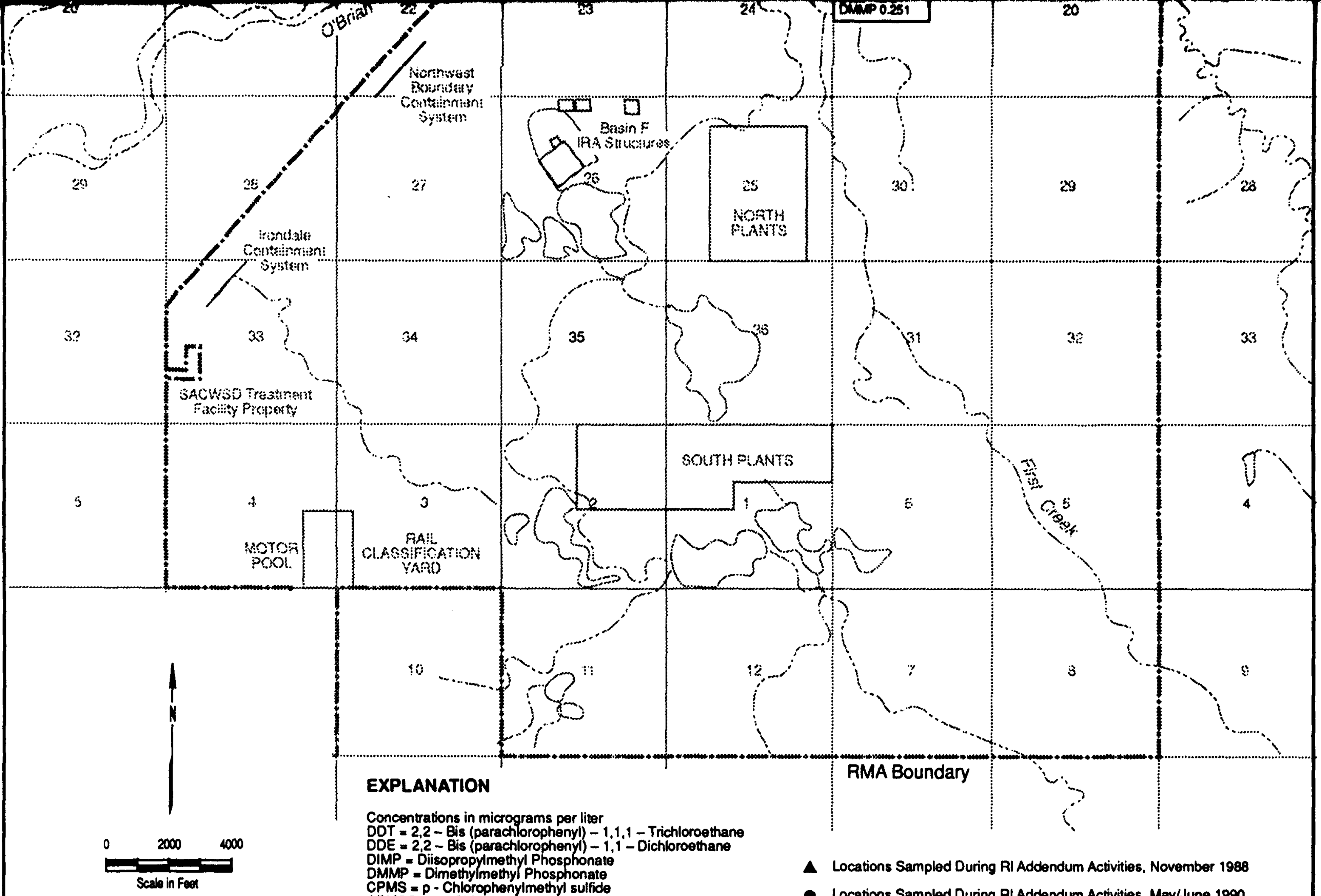
Figure 16

DISTRIBUTION OF ORGANOCHLORINE PESTICIDES DETECTED IN OFFPOST SOIL

RMA1 1143



Barr Lake
ND
(ND)
Third
Creek
Second
Creek
South Platte River
DIMP 1.33
DIMP 1.11
DDT 0.184
DDE 0.389
DIMP 0.532
DIMP 0.840
DIMP 2.91
Atrazine 4.13
(Atrazine 4.58)
Atrazine 6.80
Chlordane 0.338
DIMP 59.0
DCPD 7.43
Dieldrin 0.147
DIMP 5.90
DMMP 0.238
CPMSO2 19.4
DIMP 6.11
DMMP 0.257
Dithiane 44.2
DIMP 5.47
DMMP 0.209
Chloroform 0.599
DIMP 13.1
DMMP 4.92
DIMP 4.92
DMMP 0.227
RMA Boundary
ND
ND
Ditch
Burlington
O'Brian Canal
North Boundary Containment System
CPMSO2 170
CPMSO 120
Dieldrin 0.0760
DIMP 4.76
DMMP 0.251
Northwest



EXPLANATION

Concentrations in micrograms per liter
DDT = 2,2 – Bis (parachlorophenyl) – 1,1,1 – Trichloroethane
DDE = 2,2 – Bis (parachlorophenyl) – 1,1 – Dichloroethane
DIMP = Diisopropylmethyl Phosphonate
DMMP = Dimethylmethyl Phosphonate
CPMS = p - Chlorophenylmethyl sulfide
CPMSO = p - Chlorophenylmethyl sulfoxide
CPMSO2 = p - Chlorophenylmethyl sulfone
ND = Not Detected at or above the Certified Reporting Limit

▲ Locations Sampled During RI Addendum Activities, November 1988
● Locations Sampled During RI Addendum Activities, May/June 1990
( ) Duplicate Sample Results

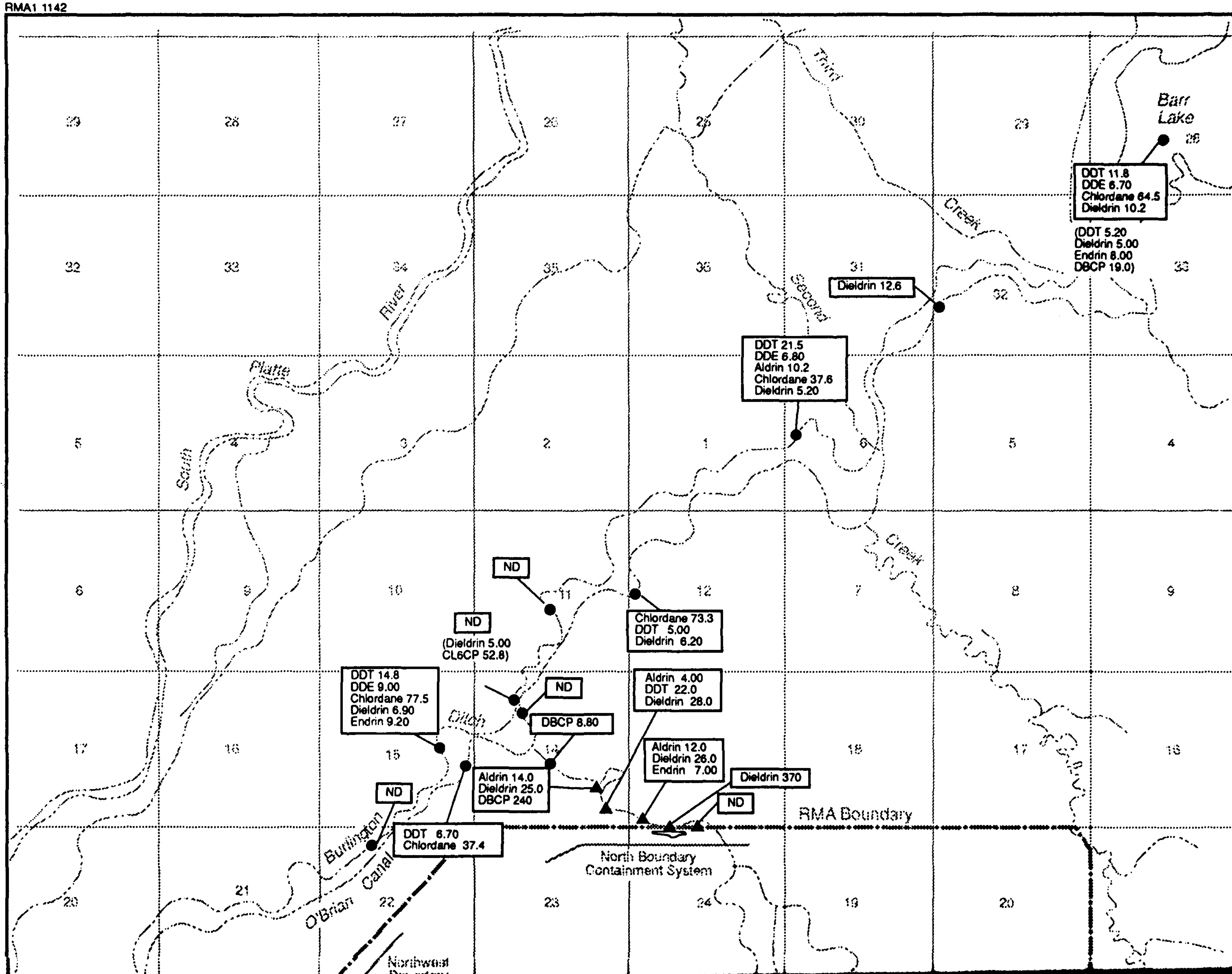
Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

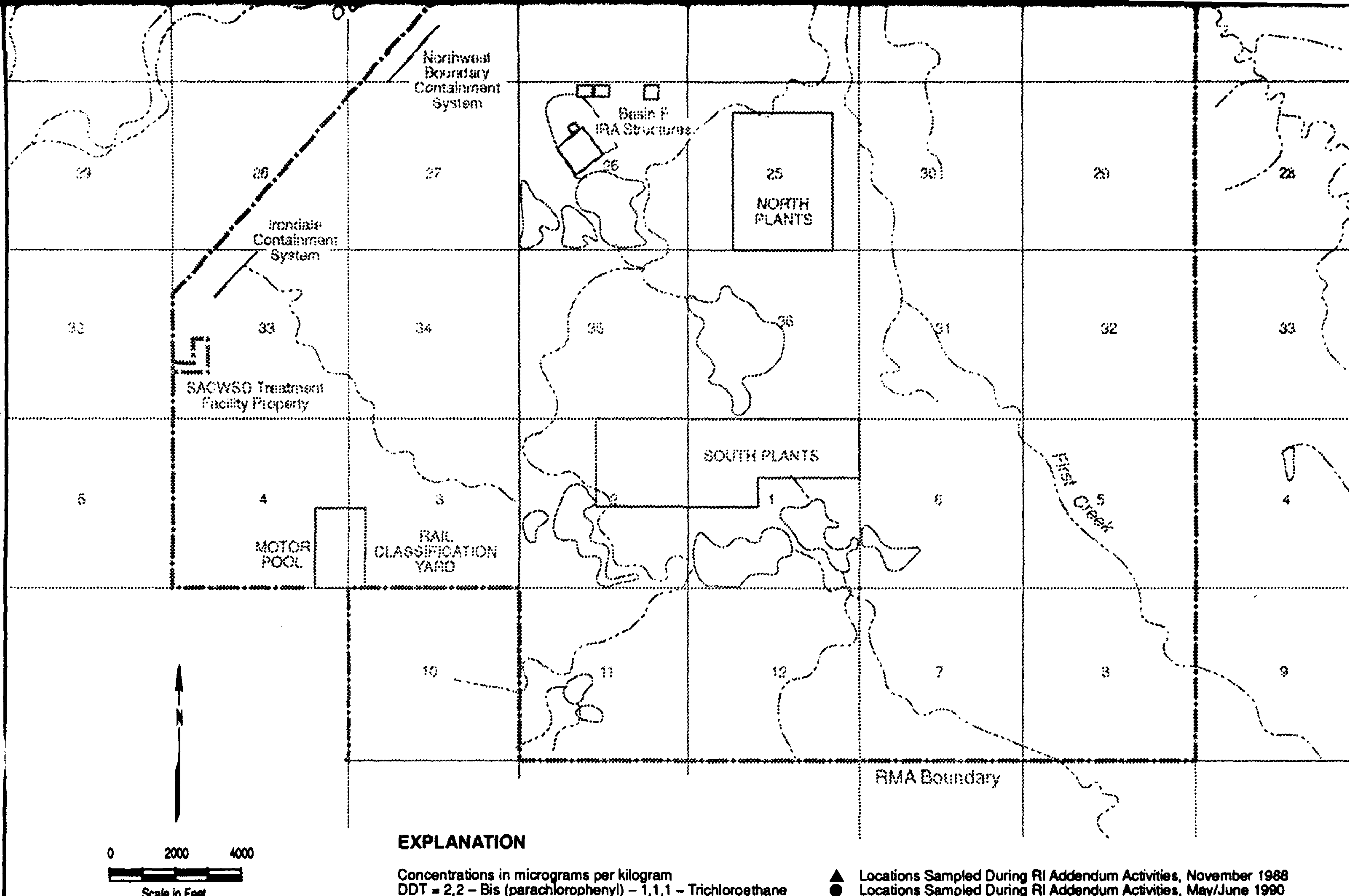
Figure 17

DISTRIBUTION OF ORGANIC COMPOUNDS DETECTED IN OFFPOST OPERABLE UNIT SURFACE WATER

RMA1 1142



Barr Lake
DDT 11.8
DDE 6.70
Chlordane 64.5
Dieldrin 10.2
(DDT 5.20
Dieldrin 5.00
Endrin 8.00
DBCP 19.0)
Third
Creek
Second
Dieldrin 12.6
DDT 21.5
DDE 6.80
Aldrin 10.2
Chlordane 37.6
Dieldrin 5.20
Creek
South
Platte
River
ND
ND
(Dieldrin 5.00
CL6CP 52.8)
Chlordane 73.3
DDT 5.00
Dieldrin 6.20
DDT 14.8
DDE 9.00
Chlordane 77.5
Dieldrin 6.90
Endrin 9.20
ND
DBCP 8.80
Ditch
Aldrin 4.00
DDT 22.0
Dieldrin 28.0
Aldrin 12.0
Dieldrin 26.0
Endrin 7.00
Aldrin 14.0
Dieldrin 25.0
DBCP 240
Dieldrin 370
ND
ND
RMA Boundary
DDT 6.70
Chlordane 37.4
Burlington
O'Brian Canal
North Boundary
Containment System
Northwest



EXPLANATION

Concentrations in micrograms per kilogram
DDT = 2,2 – Bis (parachlorophenyl) – 1,1,1 – Trichloroethane
DDE = 2,2 – Bis (parachlorophenyl) – 1,1 – Dichloroethane
DBCP = Dibromochloropropane
ND = Not Detected at or above the Certified Reporting Limit

▲ Locations Sampled During RI Addendum Activities, November 1988
● Locations Sampled During RI Addendum Activities, May/June 1990
( ) Duplicate Sample Results

Prepared for:
Program Manager for
Rocky Mountain Arsenal

Commerce City, Colorado

Figure 18

DISTRIBUTION OF ORGANIC COMPOUNDS DETECTED IN OFFPOST OPERABLE UNIT STREAM-BOTTOM SEDIMENT

(2)

GLOSSARY

$\mu g/g$	micrograms per gram
$\mu g/kg$	micrograms per kilogram
$\mu g/l$	micrograms per liter
ABS	chemical-specific absorption factor
ACGIH	American Conference of Government Industrial Hygienists
AChE	acetylcholinesterase
ADI	acceptable daily intake
ANOVA	Analysis of Variance
AOP	advanced oxidation process
APEG	alkali metal polyethane glycol
AQCDs	Air Quality Criteria Documents
ARAR	applicable or relevant and appropriate requirement
Army	U.S. Department of the Army
AT	averaging time
ATP	adenosine triphosphate
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BAC	Biotechnology Advisory Committee
BAF	bioaccumulation factor
BCF	bioconcentration factor
BCRL	below certified reporting level
BDAT	best demonstrated technology
BDL	below detection limit
BEST	basic extraction sludge treatment
BF	bioavailability factor
bgs	below ground surface

BHC	benzene hexachloride
BMF	biomagnification factor
BOD	Biological Oxygen Demand
bw	body weight
C/I	commercial/industrial
CAA	Compliance Assurance Agreement
CAR	Contamination Assessment Report
CBSG	Colorado Basic Standards for Groundwater
CCP	Composite Correction Plan (CWA)
CCR	Colorado Code of Regulations
CD	Consent Decree
CDH	Colorado Department of Health
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF&I	Colorado Fuel and Iron
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfs/mi	cubic feet per second per mile
cm	centimeters
cm/sec	centimeters per second
cm/hr	centimeters per hour
cm^2	centimeters squared
CMP	comprehensive monitoring program
CNS	central nervous system
COC	chemical of potential concern
COD	Chemical Oxygen Demand
COE	U.S. Army Corps of Engineers
CPMS	4-chlorophenylmethyl sulfide

CPMSO	4-chlorophenylmethyl sulfoxide
$CPMSO_2$	4-chlorophenylmethyl sulfone
CRL	certified reporting limit
CSC	Chemical Sales Company
CTM	cattail marshes
CU	consumptive use
CV	coefficient of variation
C_w	chemical concentration in water
CWA	Clean Water Act
DAA	detailed analysis of alternatives
days/yr	days per year
DDD	3,2-bis (para-chlorophenyl)-1,1-dichloroethane
DDE	2,2-bis (para-chlorophenyl)-1,1-dichloroethene
DDT	2,2-bis (para-chlorophenyl)-1,1,1-trichloroethane
DIMP	diisopropyl methylphosphonate
DNA	deoxyribonucleic acid
DOC	dissolved organic carbon
DRCOG	Denver Regional Council of Governments
DRE	Destruction/Removal Efficiency
DSA	development and screening of alternatives
EA	endangerment assessment
Ebasco	Ebasco Services, Inc.
EC_{50}	median effective concentration
ED	exposure duration
EDB	ethylene dibromide
EF	exposure frequency
EFH	exposure factors handbook

Eh	redox potential
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESE	Environmental Science and Engineering, Inc.
ET	exposure time
FF	fallow field
FFA	Flammable Fabrics Act
FS	feasibility study
ft/day	feet per day
ft/ft	feet per foot
ft/yr	feet per year
FWCA	Fish and Wildlife Coordination Act
FWPCA	Federal Water Pollution Control Act
FWRIR	Final Water Remedial Investigation Report
FY	Fiscal Year
FY88	fiscal year 1988
FY90	fiscal year 1990
g/cm^3	grams per cubic centimeter
g/l	grams per liter
g/day	grams per day
GAC	granulated activated carbon
GC/MS	gas chromatography/mass spectroscopy
GMP	groundwater monitoring program
gpm	gallons per minute
GWF	grasses and weedy forbs
HA	health advisory
HADs	Health Assessment Documents

HBC	health-based criteria
HDPE	High Density Polyethylene
HEA	Health Effects Assessment
HEAST	Health Effects Assessment Summary Tables
HEEDs	Health and Environmental Effects Documents
HEEPs	Health and Environmental Effects Profiles
HEW	Health Education and Welfare
HI	Hazard Index
HLA	Harding Lawson Associates
hr/day	hours per day
HSDB	Hazardous Substance Database
ICP	inductively coupled plasma
ICS	Irondale Containment System
IRA	Interim Response Action
IRF	In-situ Radio Frequency
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
ISV	in-situ vitrification
K_{oc}	organic carbon coefficient
K_{ow}	octanol/water partition coefficient
l/day	liters per day
l/kg	liters per kilogram
l/cm^3	liters per centimeter cubed
LAER	Lowest Achievable Emission Rate
lb/acre	pounds per acre
LC_{50}	chemical concentration that is lethal to 50 percent of the exposed population
LD_{50}	chemical dose that is lethal to 50 percent of the exposed population

Ldn	day-night average noise level
LDPE	low-density polyethylene
LDR	Land Disposal Restrictions
LOAEC	lowest-observed-adverse-effect concentration
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effect concentration
LOEL	lowest-observed-effect level
m^2/day	square meters per day
MATC	Maximum Allowable Tissue Concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MER	Colorado Division of Water Resources Master Extract Register
MF	modifying factor
mg/kg-bw-day	milligrams per kilogram body weight per day
mg	milligrams
mg/cm^2	milligrams per cubic centimeter
mg/kg/day	milligrams per kilogram per day
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
mg/m^2/day	milligrams per meter squared per day
mg/m^3	milligrams per cubic meter
mi^2	square miles
MKC	Morrison-Knudsen Corporation
MKE	Morrison-Knudsen Engineers, Inc.
MKES	MK-Environmental Services
ml/g	milliliters per gram
MLE	most likely exposure

MOP	Method of Proportion
MP	Malcolm-Pirnie, Inc.
MRL	minimal risk level
MSL	Mean Sea Level
MSMA	monosodium methanearsenate
N	nitrogen
NAAQS	National Ambient Air Quality Standards (CAA)
NAS	National Academy of Sciences
NBCS	North Boundary Containment System
NCI	National Cancer Institute
NCP	National Contingency Plan
NEPA	National Environmental Policy Act (1969)
NESHAPS	National Emissions Standards for Hazardous Air Pollutants (CAA)
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
NOEL	no-observed-effect level
NPDES	National Pollutant Discharge Elimination System (CWA)
NPDWS	National Primary Drinking Water Standards
NPL	National Priorities List (CERCLA)
NRC	National Research Council
NRCC	National Research Council of Canada
NSPS	New Source Performance Standards (CAA)
NTP	National Toxicology Program
NWBCS	Northwest Boundary Containment System
O&M NBCS	Operation and Maintenance North Boundary Control System

OCP	organochlorine pesticide
OECD	Organization for Economic Cooperation and Development
OHM/TADS	Oil and Hazardous Material/Technical Assistance Data System
OSWER	Office of Solid Waste and Emergency Response
OTSP	organics in total suspended particulates
OU	operable unit
PACT	powder activated carbon treatment
PC	permeability coefficient
PEG	polyethylene glycol
PFF	plowed fallow field
PM-10	respirable particulates less than 10 microns in diameter
PMO	Program Managers Office
PMRMA	Program Manager for Rocky Mountain Arsenal
POTW	publicly owned treatment works
ppm	parts per million
PQL	Practical Quantitation Limit
PRG	preliminary remediation goal
PSD	Prevention of Significant Deterioration
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
R	retardation factor
RA	risk assessment
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RBC	rotating biological contractor
RCC	Resource Conservation Corporation
RCRA	Resource Conservation and Recovery Act

RD/RA	Remedial Design/Remedial Action (CERCLA)
RD	Remedial Design
RfD	reference dose
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RIC	Resource Information Center
RLSA	R.L. Stollar & Associates, Inc.
RMA	Rocky Mountain Arsenal
RME	Reasonable Maximum Exposure
RNA	ribonucleic acid
ROD	Record of Decision
RPM	Remedial Project Manager (CERCLA)
RPO	representative process option
RSA	regional statistical area
RTECS	Registry of Toxic Effects of Chemical Substances
SA	skin surface area
SACWSD	South Adams County Water and Sanitation District
SARA	Superfund Amendments and Reauthorization Act (1986)
SAS	Statistical Analysis System
SDWA	Safe Drinking Water Act
SF	slope factor
SGOT	serum glutamate-oxymate aminotransferase
SIP	State Implementation Plans
SUTRA	Saturated-Unsaturated Transport
SVOC	semivolatile organic compound
TAC	time for exchange of basement air
TBC	to be considered

TCHD	Tri-County Health Department
TCOC	tissue chemicals of concern
TERIS	Teratogen Information System
TG-W	tall grass wetlands
TICs	tentatively identified chemicals
TLV	threshold limit value
TPP	technical program plan
TRCLE	trichloroethylene
TRV	toxicity reference value
TSD	Technical Support Document (or) Treatment, Storage, and Disposal
TSP	total suspended particulates
TSS	total suspended solids
TWA	time-weighted average
UAFS	unconfined alluvial flow system
UF	uncertainty factor
UFS	unconfined flow system
UIC	Underground Injection Control
UL90	upper 90 percent confidence limit on the arithmetic mean
UL95	upper 95 percent confidence limit on the arithmetic mean
USABRDL	U.S. Army Biomedical Research and Development Laboratory
USAF	U.S. Air Force
USC	Unified Soil Classification (or) United States Code
USDA	U.S. Department of Agriculture
USDHEW	U.S. Department of Health Education and Welfare
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTM	universal transverse mercator

USC	United States Code
UV	ultraviolet
VAR	ratio of basement volume to surface air in contact with soil
VLT	very low toxicity
VOC	volatile organic compound
WES	U.S. Army Engineer Waterways Experiment Station
WF	weedy forbs
WHO	World Health Organization
WWC	Woodward-Clyde Consultants
°C	degrees Celsius